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TRANSACTIONS *of the*

ILLUMINATING ENGINEERING SOCIETY

Founded in London in 1909 and incorporated in 1930

Volume 24 Number 1 — 1959

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TRANSACTIONS *of the* ILLUMINATING ENGINEERING SOCIETY

Volume 24 Number 1 1959

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The Illuminating Engineering Society

Golden Jubilee, 1959

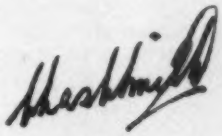
THROUGHOUT the whole of this year, for the first part of which I have the honour to be President, The Illuminating Engineering Society will be celebrating its Golden Jubilee, and it is with great pleasure and confidence that I write this Golden Jubilee Year Message.

There is no doubt that lighting, particularly artificial lighting, is playing an increasingly important and vital part in all our lives to-day, with the result that the need for and value of the Society has never been more real.

The congratulatory messages, appearing on the following pages, received from the Prime Minister and from the Presidents of kindred scientific and professional societies give evidence of the esteem in which the Society is held; I feel sure it is true to say that those far-sighted men who founded the Society in 1909, no matter how enthusiastic and inspired, could hardly have foreseen how it would grow and develop in the following 50 years.

The Jubilee Committee, under the energetic and able direction of its Chairman, Mr. A. G. Penny, together with the local Centre Committees, have worked conscientiously and diligently over the last two years to prepare a programme of national and local activities worthy of the occasion. It is my earnest hope that all members will give willingly and wholeheartedly of their time and energy to support a programme which, I feel certain, will do much to bring to the notice of all the part The Illuminating Engineering Society is playing in creating and fostering a general recognition of the need for good lighting everywhere.

Great as the technical developments of the last 50 years have been, there is no doubt, in my mind, that they will be eclipsed in the next half century, and with that challenging and stimulating thought in mind I would conclude my message by emphasising to all members the great need for enthusiastic and consistent participation in each and every one of the Society's many and varied activities, not only during this historic year, but also in the years to come.



President

Messages of congratulation

The Prime Minister

THE RT. HON. HAROLD MACMILLAN, M.P.

I AM glad to congratulate The Illuminating Engineering Society on its Golden Jubilee.

From the time of its foundation fifty years ago, when the familiar form of illumination was the gas mantle or the carbon filament lamp, the Society has made a valuable contribution to the progress achieved in lighting techniques. I am sure it will continue to do so in the years to come.

At the present time, when technical progress is proceeding so swiftly, it is essential to the nation's well-being that the results of research should achieve quick application. I know it is one of the primary concerns of the Society to ensure that in the field of illumination there is a minimum time lag between an achievement in the laboratory and its practical application.

I wish you every success in your important work.

Harold Macmillan

The Royal Society

SIR CYRIL HINSHELWOOD, M.A., D.SC., PRESIDENT

I AM glad to be able to send congratulations and good wishes to The Illuminating Engineering Society on the occasion of its Golden Jubilee.

The application of science is a powerful help in providing the necessities of life and in increasing the amenities, and your Society contributes in a very valuable way in both these respects.

C. N. Hinshelwood

The Royal Society of Arts

SIR ALFRED BOSSOM, F.R.I.B.A., M.P., CHAIRMAN OF COUNCIL

THE Royal Society of Arts sends an enthusiastic message of congratulation to The Illuminating Engineering Society on this, the occasion of its Golden Jubilee.

Many will remember that in 1910 the Royal Society of Arts recorded in its *Journal* that the work of the first Session of The Illuminating Engineering Society had "fully demonstrated" its value to the community. This usefulness has been persistently maintained throughout the last fifty years, and the stimulus which your Society has given to progressive developments in the science and the art of lighting has proved of the greatest benefit to the health and efficiency of the nation.

May this good work continue indefinitely.

Alfd C Bossom

The Royal Institution

LORD BRABAZON OF TARA, P.C., G.B.E., M.C., PRESIDENT

THE Royal Institution of Great Britain extends its most cordial greetings and congratulations to The Illuminating Engineering Society on the occasion of the celebration of its Golden Jubilee. The Royal Institution recalls with great satisfaction that it was in this Institution that Humphrey Davy first showed the potentialities of electricity in illumination by means of the electric arc, and that Michael Faraday performed the experiments that established the fundamental principles of electromagnetism, on the basis of which the generation of electrical power has become possible, with wide applications in modern methods of illumination.

The Royal Institution appreciates with almost paternal pride the valuable work that has been done during the past half century by The Illuminating Engineering Society in fields so near to its own interests and extends its good wishes to the Society for its continued success in the future.

Brabazon of Tara

The Royal Institute of British Architects

BASIL SPENCE, O.B.E., A.R.A., A.R.C.A., PRESIDENT

ON behalf of the Royal Institute of British Architects, I offer congratulations to The Illuminating Engineering Society on its great achievements during the last fifty years, during which the science and skill of its members have transformed the night scene entirely.

The contribution to architecture has been a vital one—not only to modern buildings, where lighting is accepted as an integral part—but also to historic monuments whose beauty and grandeur has been magically enhanced by floodlighting.

As a result of the progress over the first half of the century an immense field stretches into the future and the prospects for architects and lighting engineers working together with understanding, are exciting beyond imagination.

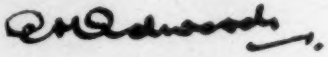
Bruce Spence

The Institution of Gas Engineers

E. M. EDWARDS, PRESIDENT

I AM delighted, on behalf of The Institution of Gas Engineers, to congratulate The Illuminating Engineering Society upon its Golden Jubilee. In its 50 years the Society has made outstanding contributions to lighting technique and has acquired a high reputation both nationally and internationally. In particular the I.E.S. Code for Lighting in Buildings has become universally acknowledged as an authoritative document on lighting practice.

I am confident that if the progress made by the Society during its first half century is continued, a very bright future lies ahead.



The Institution of Electrical Engineers

S. E. GOODALL, M.SC.(ENG.), F.Q.M.C., PRESIDENT

IT is with great pleasure that I send to you, on the occasion of the celebration of the Golden Jubilee of The Illuminating Engineering Society, greetings and good wishes from The Institution of Electrical Engineers.

The Illuminating Engineering Society can look back with pride on the progressive improvement, since those early days, now fully fifty years ago, in standards of lighting, and with them improvements in comfort and convenience both in the factory and in the home. In this process the I.E.S. Code for Lighting in Buildings, first introduced in 1936, has played a conspicuous part.

I take pride in the fact that more than one of the early founders of The Illuminating Engineering Society also attained high office in The Institution which I serve.

With every good wish for the continued progress and well-being of the I.E.S. throughout its next fifty years and beyond.

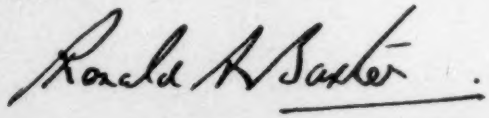
The British Optical Association

RONALD A. BAXTER, PRESIDENT

THE British Optical Association, which has the honour to be one of the Society's Sustaining Members, and has itself celebrated its Diamond Jubilee in 1955, sends its very warm congratulations on the attainment of your Golden Jubilee and on your distinguished work of the past half century.

No professional body outside your Society can appreciate the importance of your work more than ourselves. As opticians, our professional task is interlinked with yours; efficient and comfortable vision is the end to which we equally contribute.

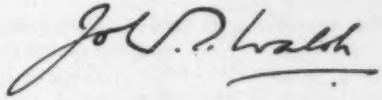
May the events of your Jubilee Year be long remembered, and may your future be as bright as your past.



International Commission on Illumination

J. W. T. WALSH, O.B.E., M.A., D.SC., M.I.E.E., PRESIDENT

I SHOULD like to congratulate the British Illuminating Engineering Society on the completion of 50 years of highly successful work in the furtherance of good lighting. The C.I.E. has always enjoyed the active support of the I.E.S., and an outstanding example of this is the fact that a prominent member of the Society, Sir Clifford Paterson, took a very active part in the formation of the Commission and was its Honorary Secretary throughout (except for the period of his presidency) until his death. The C.I.E. wishes the Society continued success in a future of ever widening realisation of the importance of good lighting to all members of the community.



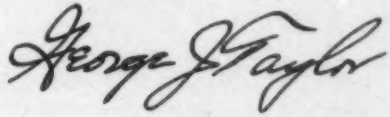
The Illuminating Engineering Society of the U.S.A.

GEORGE J. TAYLOR, PRESIDENT

THE members of this Society, through the Officers and Council, extend greetings to The Illuminating Engineering Society, London, on the occasion of its Golden Jubilee.

The technical leadership of your Society has served through the past fifty years as a source of stimulation and guidance. Among the many outstanding leaders, we think especially of R. J. Lythgoe in visual acuity, W. S. Stiles in glare and luminosity functions, B. H. Crawford in glare and color vision, P. J. Waldram in daylighting, J. M. Waldram in street lighting, visibility under varying atmospheric conditions, luminous environment analysis, J. W. T. Walsh in photometry, H. C. Weston in visual performance and industrial vision, R. G. Hopkinson in glare and daylighting, W. D. Wright in colorimetry, and H. Hartridge in color vision.

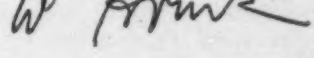
The Technical Committees of our Society have recognized these advances by constant study of your Transactions. We look forward to the continued association and exchange of information between our respective memberships and the cooperation of our efforts toward the common goal.



Lichttechnische Gesellschaft e.V.

PROF. DR.-ING. W. ARNDT, PRESIDENT

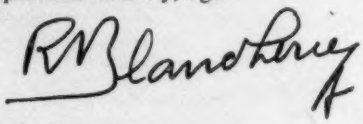
ON the occasion of the Golden Jubilee marking the 50th anniversary of The Illuminating Engineering Society, the Lichttechnische Gesellschaft e.V. in Germany sends its sincere good wishes to its kindred society in England. During the last half century we lighting engineers in our technical societies have forged more and more bonds between us, especially through our co-operative work within the C.I.E. May these bonds of friendship grow ever stronger! Moreover, may our societies in the future see still further and finer results of our endeavours in the cause of more and better light.



Association Française des Eclairagistes

ROBERT BLANCHERIE, PRESIDENT

THE Association Française des Eclairagistes sends to its elder sister, The Illuminating Engineering Society, best wishes on the occasion of the Society's Jubilee and congratulations on the magnificent work accomplished by the Society in the service of the science of illumination. May the very happy relations between our two societies grow ever closer and enable us more and more effectively to achieve our common aim to further man's well-being by teaching him how to use that indispensable amenity, light.

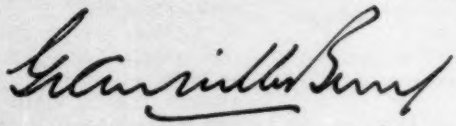


The Association of Public Lighting Engineers

GRANVILLE BERRY, M.INST.C.E., M.INST.MUN.E., PRESIDENT

IT gives me much pleasure, on behalf of the Association of Public Lighting Engineers, to send congratulations and good wishes on the occasion of the Golden Jubilee of The Illuminating Engineering Society.

During the past 50 years there has been tremendous progress in the field of illuminating engineering and public lighting in which your Society has played a leading part, and with the rapidly developing use of nuclear energy for the generation of electricity we can look forward to even greater achievements in the years that lie ahead. I wish The Illuminating Engineering Society continued success in the future.

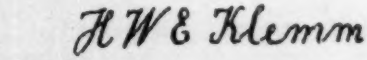


The Illuminating Engineering Societies of Australia

H. W. E. KLEMM, NATIONAL PRESIDENT

THE Illuminating Engineering Societies of Australia, commencing their activities twenty-one years after the founding of your Society, have received great encouragement from the development of the profession of illuminating engineering in the United Kingdom; your fifty years of life have resulted in the status of our profession being firmly established alongside the other branches of engineering.

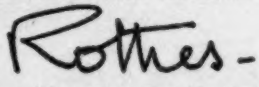
We congratulate your Society on its splendid record of achievements and are convinced that your future will be no less illustrious.



The Institute of Ophthalmology

THE RT. HON. THE EARL OF ROTHES, CHAIRMAN

IT is with the greatest of pleasure that I send a congratulatory message to The Illuminating Engineering Society on the occasion of its Golden Jubilee. There is no doubt that the revolution which has gradually occurred in illumination, particularly in factories, throughout this country during the period of the life of the Society is largely due to its efforts. For this British Industry is in the Society's debt, and we in the Institute of Ophthalmology of the University of London have been particularly interested in all its activities. With our congratulations we send our best wishes and our hope that your usefulness will not only be maintained but increased in the future.



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Presidential Address

Light and Life

By C. C. SMITH, M.I.E.E. (*Fellow*)

Standing, as I do, on what we revere as almost hallowed ground, where trod the feet of men as famous and renowned, in the fields of science and learning, as Sir Humphrey Davy and Michael Faraday, I am at once both humble and proud. Humble because of the eminence and stature of my predecessors in this high office, and proud because I am deeply conscious of the honour you, my friends and colleagues, have conferred upon me by electing me as your President for the ensuing year. That I shall be able to live up to the very high standard initially set, many years ago, by men of the calibre of Professor Silvanus Thompson and Sir Clifford Paterson, and well maintained by their successors through the years, is, I know, most improbable, but you may rest assured that I shall do my utmost to do all you would have me do, to the best of my ability.

This address which, by custom and tradition, is the first public duty undertaken by the President of our Society in his year of office, always necessitates considerable thought and concentration, not so much because of the importance of the occasion or even possibly of the ramifications and intricacies of the subject, but simply because of the difficulty, which grows as each year passes, of choosing a subject.

Recent spectacular and momentous advances in the world of science and engineering have opened up tremendous possibilities, and indeed opportunities, for all engaged in this most important and influential sphere of human activity and it was this fact coincidental with the imminence of our Golden Jubilee as a cultural society, that prompted me to give my address the simple but far reaching title " Light and Life."

There is no doubt whatsoever that we stand at the threshold of a new age, an age in which electronics, already playing a very important part in our everyday life, and atomic energy together, may well change the whole pattern of our existence. If used wisely and with sincerity it may well be that the next major problem facing us will be that of how best we should spend our leisure time, but if used carelessly and without due consideration for others, untold misery and hardship could well ensue. Against such an impressive background, one, particularly the uninitiated, might well wonder where indeed can lighting, natural or artificial, play its part, but the more one considers the fullness of life in this modern age, with its 24-hour day, its work and industry, its speed of living and commerce, its sport and pleasure, the more one realises that, without artificial lighting, the whole pattern of life would be changed beyond recognition. Quite obviously the hours of natural lighting are hopelessly insufficient for modern needs, and consequently the science or art with which we are all so closely connected, pervades practically every aspect of our everyday lives.

The Commencement of Life

It plays an extremely important part in the commencement and propagation of life of all kinds, animal and vegetable, and in order to bring to mind just how true this statement can be, I would draw your attention to the intensive research and resulting progress witnessed in recent years in, to mention just one or two of the more publicised activities, the irradiation of plant life, pig rearing, the incubation and brooding of chickens, and, of course, the increasing use of modern equipment in hospitals and maternity homes.

In the science of plant irradiation the chief processes are as follows :—

(*a*) Photosynthesis, or carbon assimilation,
(*b*) respiration,
(*c*) transpiration, or the loss, by the leaves, of water in the form of vapour,
(*d*) tropisms, or movements,
(*e*) translocation, or the transport of food material from one region of a plant to another,
(*f*) photoperiodism, or specific requirements of relative periods of day and night.

All these functions are influenced to some degree by the light falling on the plant, and in the two most important ones, photosynthesis and photoperiodism, light is the major factor. Whilst certain benefits of plant irradiation are indisputable, it should be remembered, and the obvious lesson therefrom carefully noted, that in almost all cases it is important that plants subjected to this treatment should have at least six hours of unbroken darkness per day, a fact which we human animals might well bear in mind. In certain of

Presented at a meeting of the Society held in London on October 14, 1958.

the examples of life propagation I have quoted it is not clear whether light or heat is the more important in achieving the desired result, but frequently it is a combination of both, and invariably " lamps " of one kind or another are utilised. This is very true in the case of the specific examples I happen to have mentioned but there can be no doubt that, in respect of modern maternity homes and hospitals, artificial lighting of a very high quality and standard, particularly in operating theatres, has rendered indisputable and invaluable service to the medical profession.

In this connection it may be of interest to quote the official figures for infant and maternal mortality rates over the last 30 years, which are as follows :—

	1927	1957	Decrease
Infant Mortality Rate (per 1,000 live births)	94	26	72%
Maternal Mortality Rate (per 1,000 births)	4.2	0.42	90%

Whilst it is true to say that lighting cannot claim all the credit for this tremendous improvement, those in authority are the first to affirm that artificial lighting, providing excellent facilities in the most hygienic way, can claim much of the credit.

The Sustainment of Life

Having made its considerable contribution towards the commencement or propagation of life, artificial lighting then proceeds to play an equally important part in the sustainment of life, in which our standard of living must surely be a most significant factor. In order that this may be preserved at a reasonably high level, it is essential, in this small and densely populated country of ours, that an extremely high rate of production must also be maintained and, if possible, improved. Here indeed, if anywhere, have improvements in lighting proved of inestimable value, for the results of better lighting, on production, both directly by speeding and improving works processes, and indirectly, by decreasing accidents and creating a pleasant environment for work, have been unmistakably recognised in all spheres of industry.

Lighting in factories and works of all kinds, and in coal mines has, in this way, contributed greatly to the nation's well-being, and the following figures, representative of factory experience and Government investigation, published by the Lighting Service Bureau, as it was at the time, give some indication of the scope and magnitude of this contribution.

Type of work	Rise in production consequent upon increased lighting (per cent)
Woodworking...	25
Weaving (rayon)	13
Fine micrometer work ...	10
Thread winding and finishing	10
Tile pressing	10
Type setting	24

The above figures convey the direct and concrete results of lighting improvements, but give no real indication of the improved quality of the work or the improvement in health and outlook of personnel due to working in more pleasant surroundings.

Such increases in production are not attributable solely to increased illumination values but also, to an almost unbelievable extent, to better quality lighting.

Another direct result is that of reducing accidents, thereby indirectly increasing production and improving working conditions, and the following examples, which have been reported by the factories concerned, clearly indicate the trends.

Type of work	Decrease in accident rate consequent upon increased lighting (per cent)
General engineering	20
Fine engineering (rubber leather products)	25
Heavy engineering	20
Cold rolling	51

The Preservation of Life

In considering the many diverse ways in which light is connected with life, the next broad category could well be the preservation of life, in which the prevention of accidents on the roads makes a significant contribution and where the use of statistics is of considerable value. Statistics, however, are notoriously suspect, mainly due, in my opinion, in many cases, to careless or unintelligent interpretation of the figures supplied. There is no doubt that frequently it is difficult to stabilise conditions in order that reliable comparisons can be made, and results of any value deduced therefrom. Particularly has this been found to be so in the compilation of statistics to show the relationship between street lighting and accidents, but great efforts have been and continue to be made to this end and the latest figures, contained in an unpublished report by

the Road Research Laboratory, indicate that :—

(1) the latest data confirm earlier work which showed that the provision of good modern street lighting usually reduces the figure of injury accidents in darkness. The old and new data combined, give an average reduction of 30 per cent ;

(2) there is fairly strong evidence that the reduction in pedestrian accidents is greater than the reduction in other types of injury accident;

(3) amongst the accidents that do occur, deaths and serious injuries are appreciably reduced.

In an indirect and general way, improvements in lighting have also undoubtedly helped to preserve or save life by being responsible in no small way, for the tremendous steps taken over recent years in the promotion of health and prevention of illness. One particular avenue by which artificial lighting is playing a great part in this sphere, is in the field of preventive medicine, where modern lighting techniques and light sources have placed in the hands of the specialist and surgeon, tremendous assistance in their never ending and sometimes heart-breaking fight against illness and disease. Light enabling them to perform the most serious and delicate operations, light from sources of extremely small physical dimensions permitting them to see the origin and development of disease actually inside the human body, and light which can be directed accurately at the source of a disease in order to alleviate pain or fight the disease at its source. Particularly is this so in the investigation of diseases of the bladder and also for ear, nose and throat complaints where small point sources of light have proved absolutely invaluable.

The Enrichment of Life

Finally and by no means of least importance connecting Light and Life, I would speak of lighting in the enrichment of life, in which general category I would place all those activities that make life so much fuller, richer, and more enjoyable for each and every one of us. The theatre, the ballet, television, the cinema, sport, art, and the opera, all of which we are able to appreciate and enjoy to the full in our homes and in the many theatres, galleries and halls in London and the Provinces. The architecture of our buildings, the love of reading good literature, both for sheer enjoyment and for learning, in all these cases artificial lighting has helped us enormously in deriving maximum enjoyment in the short time available for such pursuits. How many books fewer would be read and how much less would the public libraries and art galleries be used without good lighting, indeed, can you imagine the ballet, the opera and, most of all, the theatre, without lighting and its multitudinous wonderful effects. Nowadays, with well designed lighting installations, the works of the masters can be viewed at all hours of the day and evening and, with the increasing popularity of floodlighting, famous buildings are becoming almost as beautiful, sometimes more so, and well known by night as they are by day. The *Son et Lumiere* spectacles on the Continent have opened up new and exciting possibilities in this unique and impressive expression of the lighting art.

The value of organised sport of all kinds, in the schools, universities and the services, for the maintenance and improvement of fitness and health and for the building and development of character is now, I think, fully recognised, and with increasing demands for study and business during normal hours, most people are finding that the greater part of the time available to them for sport and recreation is during the hours of darkness. Modern methods of interior and exterior large area floodlighting, have extended " playing hours " considerably, and floodlit football, athletics, show jumping and tennis, together with many indoor games are becoming increasingly popular as a result.

The Value of the Society

I have endeavoured in my preceding remarks, to establish and emphasise just how important and vital a place, artificial lighting occupies in our lives today and it is not unreasonable to assume, from that fact, that the Society itself holds a relatively similar position. There is no doubt whatsoever in my mind of the inestimable value, to the health and well being of a country and its people as a whole, of cultural bodies of this kind, and this Society, with its monthly sessional meetings both in London and the Provinces, where members, and frequently guests of kindred organisations, come together and discuss common problems and ways of solving them, may well be proud of its contribution.

The Society, as I mentioned earlier in this address, is nearing its Golden Jubilee, 50 years indirectly in the service of the public, and in those 50 years it has quietly and unobtrusively, but nevertheless most effectively, contributed great service to the community, both as a corporate body and through its members, in the ever widening field of illumination. As is now well known, the inaugural meeting was held in 1909, and by 1911, the Society had formed Committees on Library Lighting and the Artificial Lighting of

Schools, appointed representatives to a Joint Committee which was to frame a Draft Standard Specification for Street Lighting, and had made known the desirability and its intention of forming an International Commission on Illumination, which intention was approved and supported by special resolution of the International Electrical Congress at its meeting in Turin on September 16, 1911.

It is interesting to remember that the now famous International Commission (the C.I.E.) was eventually formed as envisaged, in 1913, in Berlin. In the same year, the I.E.S. formed a Committee on Daylight Illumination in Schools and the Home Secretary appointed the first Factory Lighting Committee, the membership of which included four members of the Society.

During the first World War, the Society and its members continued their excellent work by carrying out experimental work on certain special problems for the Government and upon the cessation of hostilities it soon became obvious that the initial eagerness and enthusiasm had far from waned, for in 1919, special Committees were formed to study and report on Office Lighting, Railway Lighting and Stage Lighting.

In the years that followed, many of these Committees submitted reports which proved of tremendous value, particularly that on " Eyestrain in Cinemas," the recommendations of which have formed the basis for regulations used by Licensing Authorities ever since. The same may also be said of the work of the Factory Lighting Committee, which issued its 1st Report in 1915 and 2nd and 3rd Reports in 1921 and 1922, the Society seeing the fruits of its long continued efforts to bring about better lighting in factories when the 1937 Factories Act did include certain statutory requirements concerning lighting.

Further work by the Society and its members, worthy of special mention, is that of its representatives on the Joint Committee, formed to frame the first Draft Standard Specification for Street Lighting in 1911 and subsequently in the preparation of the Interim and Final Reports of the Ministry of Transport Departmental Committee. Finally, of course, there is the I.E.S. Code, a book which has necessitated a tremendous amount of hard work and thought, and a wealth of experience and which has justified itself time and time again as a first-class reference book of great value to all concerned with lighting.

The Future of the Society

So much then for the need for the Society and its value and place in the community today, but what of its future? I firmly believe that the main strength of organisations of this kind, lies in the individual members, not necessarily in their numbers, although that obviously is important in itself, but in their quality and calibre, in their willingness, and indeed, eagerness to sacrifice, quite voluntarily, time and energy in the desire and the will to acquire, share and disseminate knowledge. For the Society to continue to play a healthy and useful part in the well being and advancement of our country, papers must be prepared, presented and discussed, specialist committees formed to produce technical reports of great value as guides and reference books, and above all, encouragement must be given and facilities provided for the many young men who must be attracted to the profession, if we are to be able to do all these admirable things.

Furthermore, considerable care and thought must be given to the training of such young men as are attracted to our ranks because, in these modern times, when science and engineering are becoming so complex as to demand an extremely detailed and comprehensive knowledge of each subject, there is an ever increasing and, unfortunately, necessary tendency towards specialisation, and if great care is not taken we may grow and develop into a nation of specialists rather than wise men. That, for many obvious reasons, should be avoided at all costs, as it would undoubtedly eventually be to the detriment of the individual, the Society, and in the long view, to the country as a whole.

There are many who believe, myself included, that the disregard of science by humanists and of the arts by engineers, has resulted in an incomplete education, in the broadest sense, for both, and consequently the suggestion that there is a lack of men, at managerial level, with the wisdom and breadth of knowledge that spring from a sound, extensive education, might well have some substance in it.

There is an extremely wide variety of skills and knowledge associated with lighting, and members should not restrict their activities to any particular aspect, but should use the Society to broaden their interest in the many uses and arts of light.

In the same way, the Society must keep its field as wide as possible, studying not only, for example, the production of light and the use of light (natural and artificial), but also the processes of seeing. This means collaboration, joint meetings, joint committees, joint thinking, and therefore we must make every effort to stimulate and develop a spirit of co-operation between learned and cultural

societies of this type for, in my opinion, nothing but good can emanate from such a course. Not only does it broaden ones outlook to hear and endeavour to understand the problems confronting others, no matter in what sphere or field they are actively engaged, but it can, on occasion, help tremendously in the solution of ones own problems. It is surprising just how much common ground there is even in the study of such apparently widely different subjects as say surgery, photography, engineering and architecture and, quite apart from the fact that it is of considerable value to know of the difficulties encountered in other arts or sciences even if one does not comprehend the possible remedies, there can be no doubt that a new line of thought or method of application can often be gleaned from the study of a quite different but kindred subject.

I would therefore suggest that greater efforts should be made both in London and in the Provinces to make a success of more joint meetings with kindred societies and organisations, not only by inviting members to meetings of this Society but also by endeavouring to attend their meetings by invitation.

Conclusion

In conclusion therefore I would like to draw the attention of all members to the first of the objects of the Society, stated in the Memorandum of Association, which is " to promote the art, science and technology of lighting, etc., and the application of the basic sciences to the production, control and utilisation of artificial light, and the control and utilisation of natural light . . . and to facilitate the exchange of information and ideas . . . and to disseminate knowledge relating to lighting and seeing . . ." This, in itself, imposes a great responsibility on members and I feel quite confident that if we keep even only those objects immediately and permanently before us, doing all possible to fulfil them faithfully and sincerely to the best of our ability, the Society will not only attain its Golden Jubilee with considerable pride but will go from strength to strength in the years ahead.

Lastly, I would reiterate my appeal for co-operation and mutual understanding between kindred societies and organisations in order that the tendencies to confine ones activities within the watertight compartments of specialised subjects are halted and the artificial barriers to wider knowledge and understanding, existing no matter how unintentional, are removed.

In his " Reflections on the French Revolution," Edmund Burke spoke of " The men of England, the men, I mean, of light and leading in England, whose wisdom is open and direct." With such men as its members, and with the aims and efforts to which I have referred, I am convinced that the Society can enter the next fifty years of its existence, unafraid and confident.

Vote of Thanks

Mr. J. M. WALDRAM, proposing a vote of thanks to Mr. Smith, said : As the slow procession of Presidents passes across the stage of the Society year by year, I think we all come to the inaugural meeting with a feeling of special interest and anticipation as we wonder what the new President is going to say in his Address. It is an extremely personal task : his first public task, and quite the most difficult and the most important. As Mr. Smith has himself said, it does not get easier as the years go by ; we realise each year how much has already been said by his predecessors : hence the interest with which we listen to a Presidential Address, and our admiration for the distinction with which successive Presidents discharge it.

We can indeed congratulate our Society that we have such a succession of men who can do it so well. What a variety of Presidents we have had down the years : civil servants, scientists, consultants, lamp makers, medical men, technologists in plastics and glass, men from gas and electricity undertakings and, strange as it may seem, illuminating engineers. A very great variety of skills and interests has been brought to the Society, which reflects the very breadth and outlook of the Society to which the President has referred.

Mr. Smith is nearly unique among our Presidents. He is one of three men who have been President of the Association of Public Lighting Engineers as well as of this Society, and he is, as I know well, a very good engineer, and a man of sufficient stature to have his feet on the ground and his head at the top of a tower ladder at the same time. He is unique not in that, but because his job is not to devise theories or to make lighting equipment, but to use the equipment and keep it in order. Had he followed some of our Presidents and spoken of his particular interests, we might have heard some pithy comments upon the behaviour of some of the things that he buys, and he would probably have brought some breaths of fresh air into some of our more stuffy and ponderous pronouncements. But he has followed many Past Presidents, in talking to us not of his professional interests but of wider matters, the things in which he is really interested.

It is particularly appropriate as we approach

our Golden Jubilee that he should have reminded us so fully of the enormous width of our job, for it touches all life. Wherever men go and whatever they do, in home or at hospital, in public buildings or in public houses, in vehicles or ships or aircraft, at work or at play or in church, a lighting engineer has gone to help them to do it. Not only has the lighting engineer to understand the things people do in all these places and enter into their life, but he must have some knowledge of a great many arts and manufactures which go to the making of his own material. He has to be a jack of all trades, but a master of his own. That is why our job has persisted. It is small, as jobs go ; of trivial interest compared with many matters discussed from this lecture table. Yet it has persisted and been very interesting over these fifty years, because it has brought us in touch with all that is going on, and made us keep abreast of so many new things and play our part in their development. And so I hope that when our grandchildren come into this room to celebrate our centenary, it will still be a live, necessary and interesting job.

I move that the best thanks of the Society be accorded to our President for his able Address.

Mr. F. J. BURNS, in seconding the vote of thanks, said : I assume that I have been chosen to second the vote of thanks to Mr. Smith because of my long association with him and because I share with him the distinction of being a citizen of " no mean city." Although no longer a member of the Centre I can say how much the members in the Liverpool Centre appreciate and are delighted at the honour the Society has conferred upon Mr. Smith. As you know, he was—and still is—the backbone of the Liverpool Centre.

I notice from past Presidential Addresses that it has been customary to quote Edmund Burke, who is a favourite of mine. I would like to depart from that custom and quote from the works of Dr. Samuel Johnson, who said of the same Edmund Burke " He is such a man that if you met him for the first time in the street and you and he stepped aside to take shelter for five minutes, he would talk to you in such a manner that when you parted you would say ' this is an extraordinary man '." From the great breadth and vision of the Address presented to us tonight dealing with the fundamental principles of light and life as they affect us all, I think we can all say, as Dr. Johnson said of Edmund Burke, " this is an extraordinary man." May his sterling qualities continue to add light and lustre to the Society and in seconding this vote of thanks, may I convey on your behalf to him and Mrs. Smith, the sincere good wishes of us all.

UDC 628.972

Lighting Trends Since 1945: A Survey of Industrial, Office and Shop Lighting

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Summary

This paper surveys broadly the major developments in light sources and fittings since 1945 and examines the trends in British lighting practice for industrial, office and shop installations, with particular reference to four aspects: (1) Changes in illumination levels; (2) the demand for flexibility in lighting installations; (3) the practical impact of the "quality" approach on lighting design; (4) the tendency to integrate lighting with other aspects of design.

The investigation establishes a considerable increase in illumination levels, much assisted by the efficiency and low cost of fluorescent tubes. The demand for flexibility has been met in many installations by ingenious new designs, and similar successes can be recorded for the integration of lighting into the building structure. There is, however, a potential conflict between "quantity" and "quality" of illumination, integration and flexibility which, in the author's view, can only be satisfactorily settled by close co-operation between architect, engineer and lighting designer.

(1) Introduction

One of the remarkable features of the last decade or so has been the extent of new building and re-equipment in industry and commerce, and the important part which lighting has been able to play. A number of papers before this Society have drawn attention to the lighting progress made in particular fields [1, 2, 3, 4], but it is the purpose of the present paper to look for common trends and to relate them to developments in light sources and equipment, to modern practice in factory lay-out, and to office organisation and shop design. Changes in architectural approach affecting lighting ideas will be fully discussed in another paper at this Summer Meeting and they are therefore only referred to in passing.

The full story of a period during which, for the first time, artificial lighting was able to replace natural daylight, cannot be told within the narrow limits of a paper. All that can be attempted is to highlight certain trends and to examine to what extent they harmonise or conflict with each other and with present-day thinking on lighting design. Four aspects will be examined in particular, namely:—

(*a*) Changes in illumination levels;
(*b*) The demand for flexibility in a lighting installation;
(*c*) The practical impact of the "quality" approach on lighting design;
(*d*) The quest of the architect and designer for integration of lighting with the building structure.

Before examining the various fields of lighting it will be useful to make a brief review of developments in light sources and lighting equipment.

The author is with Atlas Lighting Ltd. The manuscript of this paper was first received on August 15, 1957, and in final form on March 7, 1958. The paper was presented at a meeting of the Society in Eastbourne on May 12, 1958.

(2) Light Sources

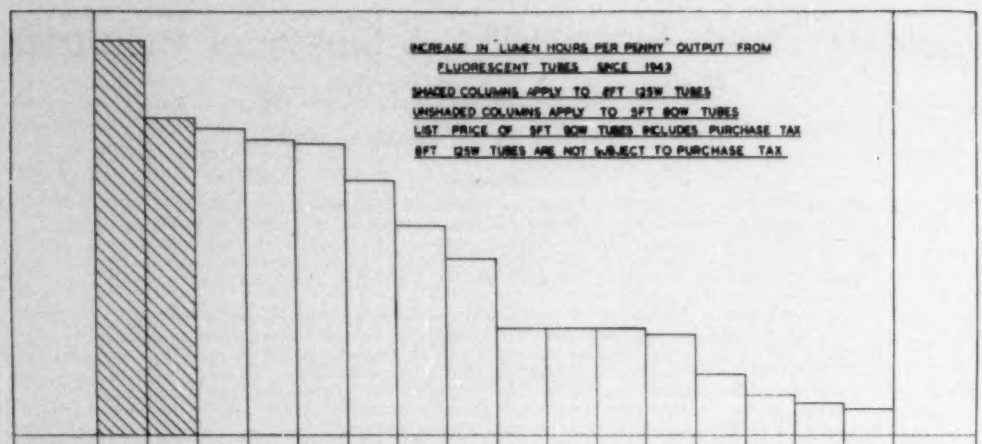
(2.1) Fluorescent tubes

The hot cathode tubular fluorescent lamp was introduced just before World War II and made a notable contribution to the war effort by providing good lighting in permanently blacked-out factories. Its use was subject to Government licence until 1946, after which it found its way into commercial, shop and other applications. Initially only one tube rating was available, namely, the 80-watt Daylight tube with a colour temperature approximating to 6,000 deg. K. Subsequently the colour of this tube was changed until today the Daylight tube approximates 4,200 deg. K. Present-day tubes comprise a range from the miniature 4-watt tube of 6 in. length on the one hand, to the 8 ft. 125-watt tube on the other. Six near-white tubes are used as well as distinct colours for decorative purposes. Of the many tubes developed for special purposes the new reflector tube may have a considerable influence on lighting design.

The steady increase in efficiency and life, coupled with drastic reductions in the price of tubes, has led to a phenomenal fall in the cost of lighting (Fig. 1) which progressively opens new fields to fluorescent tubes, and is one of the main reasons for the achievement of higher standards of lighting in this country.

(2.2) Cold cathode tubes

The cold cathode fluorescent tube was actually introduced before the hot cathode type, first in


INCREASE IN 'LUMEN HOURS PER PENNY' OUTPUT FROM FLUORESCENT TUBES SINCE 1943
SHADED COLUMNS APPLY TO 8FT 125W TUBES
UNSHADED COLUMNS APPLY TO 5FT 80W TUBES
LIST PRICE OF 5FT 80W TUBES INCLUDES PURCHASE TAX
8FT 125W TUBES ARE NOT SUBJECT TO PURCHASE TAX

YEAR	1957	1956	1956-7	1955	1954	1953	1952	1951	1950	1949	1948	1947	1946	1945	1944	1943	YEAR
LIGHT OUTPUT IN LUMENS	7125	7125	4330	4160	4000	3680	3040	3040	3040	3040	3040	3040	2160	2160	2160	2160	LIGHT OUTPUT IN LUMENS
LIFE IN HRS	5000	5000	5000	5000	5000	5000	5000	5000	3000	3000	3000	3000	3000	2000	2000	2000	LIFE IN HRS
LIST PRICE	20/-	25/-	15/8	15/8	13/2½	16/-	16/-	19/-	19/-	19/-	19/-	20/-	24/-	24/-	30/-	36/8	LIST PRICE
LUMEN HRS PER PENNY	348400	348000	264900	210600	209600	195800	79000	66650	40000	40000	40000	38000	22500	15000	12000	9850	LUMEN HRS PER PENNY

Fig. 1. Cost, life and lumen output of fluorescent tubes, 1943–1957.

colours, and then, in the late 1930s, in white. It operates at higher voltages and therefore requires special protective devices.

Compared with the early hot cathode tube, it had certain important advantages: immediate starting, long life, ability to operate under severe voltage variations, and a smaller decrease in efficiency during life. With the improvements in the hot cathode lamp in all these respects, and a trend away from unshielded light sources, the cold cathode tube has lost popularity, except for special "tailor-made" applications. Its running cost has been estimated to exceed that of hot cathode tubes by 30 per cent.[5, 6].

(2.3) Discharge lamps

The sodium lamp has undergone no important changes and, owing to its colour deficiencies, it is now little used for internal lighting. On the other hand, the range and usefulness of mercury lamps has been extended by the addition of a 1,000-watt rating and by the successful development of fluorescent mercury lamps which combine very much improved colour-rendering properties with efficiencies at least equal to those of the plain mercury lamps.

(2.4) Tungsten filament lamps

There have been no major changes in the design or performance of tungsten filament lamps, but whereas some ten years ago the question could seriously be asked whether fluorescent tubes would not eventually supersede them, it is now accepted that incandescent lamps will always have their own important part to play. In display lighting, particularly, tungsten filament lamps have been given a new lease of life with the advent of internally mirrored reflector lamps in 1948[3].

Comparison with fluorescent tubes has led to an appreciation of the fact that the colour of light from tungsten filament lamps is by no means ideal and may be distinctly unflattering. As a result, a pink lamp was introduced for domestic and social application in 1956, but in spite of its appeal it has so far made little impact.

(2.5) New light sources

During recent years, new light sources have been developed, such as the Very High Output fluorescent tube and the electroluminescent panel. These sources are in commercial use for specialised applications, the former in Light and Sound Spectacles and the latter for dark-room and

aircraft use. They have, so far, shown no signs of affecting general lighting practice.

(3) Lighting Fittings

The increased use of fluorescent tubes has encouraged the development of a great variety of lighting fittings, and it may be claimed that in fluorescent fittings design this country has, for a considerable time, held a position of leadership.

(3.1) Materials

In the early post-war period steel was extremely scarce and strictly controlled, and this forced manufacturers to employ other materials such as aluminium. Since then, sheet steel has generally been used for industrial and commercial fittings. As early as 1945 the search for a translucent material led to experiments with acetate sheet, but this material proved unstable. It was soon superseded by polymethyl methacrylate, and this material, in the form of clear ribbed sheet, was used in 1947 for the first enclosed fitting to be introduced in this country—possibly in the world. The merits of this acrylic sheet as the most adaptable and stable material for commercial lighting fittings have remained unchallenged in this country, although polystyrene has gained some acceptance, particularly for louvres and extruded panels.

Another plastic material—poly-vinyl-chloride—has proved particularly useful in corrosive atmospheres as an alternative to the vitreous enamelled steel reflector. Vinyl foil in the form of corrugated sheeting or modular panels is used in luminous ceilings.

Glass has made little headway in fluorescent lighting fittings because of its weight and fragility, but one development has been the introduction of prismatic panels for commercial lighting. Where tungsten lamps are used, however, glass prismatic units have maintained their popularity.

(3.2) Finishes

Early fluorescent fittings were cellulose-sprayed, but this finish deteriorated after very little use. Vitreous enamel remains unchallenged for reflectors for use with incandescent lamps, but this finish imposes severe limitations on the design of fluorescent fittings, and means a considerable increase in price. Vitreous enamelled fittings are therefore employed in only a small proportion of industrial installations. A stove enamel finish has proved acceptable for all normal purposes, and research in paint materials and spraying technique has led to the emergence of special stove enamel finishes which are entirely satisfactory, even under severe conditions.

(3.3) Light control

When the fluorescent tube was first introduced, one of its outstanding characteristics was its low brightness, and because of this the use of bare tubes was considered admissible. With increasing efficiency, however, tube brightness increased and soon reached a level at which it could cause discomfort, at least in larger installations. In industrial lighting, reflectors are generally employed to give a sideways shielding, but cross shielding is the exception even today. The value of directing some light upwards towards the ceiling has been accepted for many years and most fluorescent industrial fittings provide a small upward component. On the other hand, most tungsten reflectors still maintain the tunnel effect associated with a purely direct light distribution. For commercial fluorescent fittings a general light distribution provided by diffusers of clear ribbed acrylic sheet gained rapidly in popularity, but increased tube brightness brought about a change in favour of opal acrylics.

In the U.S.A. another method of light control had been developed using " egg crate " louvres and this found increasing support in this country from the early 1950s onwards. At first these louvres were made from anodized aluminium or painted steel, but later clear or opal plastic louvres were incorporated as attachments to fittings or even as completely louvred ceilings. In recent years there has been something of a revulsion against louvres, partly because of the difficulties experienced in cleaning them. On the other hand, clip-on louvres supplied in short sections have gained popularity, as these can easily be dismantled and washed.

For accurate light control with tungsten lamps mirror glass reflectors are still favoured, but anodized aluminium reflectors are often employed in display lighting and with fluorescent tubes. Directional light control of tubes in one plane has actually proved more effective than was at first thought possible.

(3.4) Design

Although interesting developments have occurred in the design of all lighting equipment, the most significant changes have been associated with fluorescent lighting. The earliest fittings were crude " pig troughs " with big humps on top to house control gear designed for entirely different purposes. After 1945 considerable effort went into streamlining their appearance and when the possibilities of fully tooled-up designs—and their

cost—became clear, ranges of fittings were conceived in which the same chassis could be used with various attachments.

The ever-widening use of fluorescent lighting brought with it an increasing variety in the shapes of fittings, but with the exception of some elaborate ornamental creations, particularly for banks, designs have remained relatively simple and contemporary: we have been spared the anachronism of "Tudor" or "Jacobean" fluorescent lighting. On the other hand, the length of the light source and the need for incorporating large and heavy control gear have tended to make designs a little clumsy, and open to Baines' criticism that they are "all too static in character to float"[8]. There are some elegant installations of multi-tube fittings of shallow cross section, but Baines' suggestion about employing free curved shapes and lines has not been followed up.

(3.5) Circuits

This survey is not concerned with the technicalities of circuitry for fluorescent lighting, as this subject has been adequately dealt with in other papers before the Society[9]. It should be recorded, however, that since the introduction of quickstarting cathode heating circuits in 1947 the use of starter switches has decreased, especially where maintenance is difficult.

Resistance circuits, particularly those using ballast lamps, have found applications mainly in small installations where initial cost is of great importance, or in shops where the colour of light from the ballast lamp may be of advantage.

(4) Industrial Lighting

(4.1) Illumination levels

Illumination levels in industry have risen very considerably since the war. A lower limit had been established by the Factory Regulations of 1941[10], which laid down that the general illumination of those interior parts of factories where people are regularly employed shall be not less than 6 lm/ft². The I.E.S. Code of 1945 recommended levels of between 10 and 20 lm/ft² for work of ordinary character, but the 1955 edition shows increases in values approximating to 60 per cent. (Table 1.)

There is every indication that the higher levels recommended in the I.E.S. Code are now widely accepted and adopted by factory managements. How has this change come about? The post-war interest in productivity no doubt led to a greater appreciation of the contribution which good lighting can make at a low cost. An equally important factor was the need for attracting

Table 1

Some recommended illumination levels in I.E.S. Codes 1945 and 1955

	1945 Code lm/ft²	1955 Code lm/ft²	Per cent. Increase
CLOTHING			
Cutting, sewing, etc....	20	30	50
FOOD			
Refining, blending, bottling, canning, etc.	10	15	50
HOSIERY			
Lockstitch machines —dark	30	50	66
Lockstitch machines —light	15	20	33
MACHINE SHOPS	10	15	50
WOOLLEN & WORSTED			
Weaving	10	15	50
Blending	7	15	100

women into industry under conditions of post-war full employment. Good conditions of work, cheerful decoration and good lighting became essential amenities, and this must be considered as one of the primary causes of the improvements achieved. Where this did not apply, e.g., in some of the older industries relying predominantly on male operatives, illumination values did not increase to the same extent.

(4.2) Flexibility and quality in lighting

Good factory lay-out is designed to achieve maximum production efficiency, and may be completely changed from time to time. A lighting installation especially designed to suit a shop lay-out today may therefore be quite unsuitable in six months' time, and costly modifications may be called for. Fortunately other developments have reduced such a risk. The increasing use of fluorescent tubes and the adoption of higher levels of illumination have led to the design of general lighting installations which are virtually shadow-free. Continuous lines of fittings are a good example of such a solution.

Whilst a general lighting scheme can cater for changes in lay-out, it is unsuitable for other changes which involve reallocation of space

Fig. 2. Flexibility of lighting trunking systems.

between factory, warehouse and office accommodation, each with a different illumination level. There was a need for a flexible lighting system, and the development of lighting trunking in the early 1950s was the answer[4, 11]. It solved a variety of problems, such as the difficulty of providing suspension points in northlight roof ceilings and of running conduits for light and power wiring overhead. Another good feature of some systems of trunking is the ease with which gear trays and reflectors can be moved in order to increase or reduce illumination levels (Fig. 2). By incorporating wiring runs for power and communication cables the trunking forms the electrical backbone of the factory installation.

General lighting is not suitable for certain situations where directional effects and shadows are important, such as in many inspection processes, and special solutions must be found. The trend away from machine lighting has perhaps gone further than desirable, and in 1950 it was reported to the National Illumination Committee of Great Britain that "supplementary local lighting has often marked effects in providing a focus of attention on the task and improved definition of detail as a result of the additional directional light component"[12]. There are signs that the advent of the miniature fluorescent tube may open up a new era of built-in lighting in machinery and tools.

Colour in industry has assumed considerable importance and the painting of structures and plant according to a carefully thought out plan can make a valuable contribution to safety and comfort. The colour of the light source plays its part in this. Early installations of daylight fluorescent tubes had often an atmosphere of gloom, and even with the higher levels of illumination used today the choice is often a light source rather warmer than the Daylight tube, such as the White or Warm White tube.

In high bay installations the plain mercury lamp was widely used, but it has been superseded by blended systems or by the fluorescent mercury

Fig. 3. Translucent industrial reflectors with 1,000-watt MBF/V mercury fluorescent lamps.

Fig. 4. High bay trunking installation using 8 ft. 125-watt fluorescent tubes.

lamp[4, 7]. The recent development of the 1,000-watt MBF/V lamp offers new opportunities (Fig. 3), but the still better colour quality of the 8 ft. fluorescent tube, coupled with its economic advantages[6], has made it increasingly popular (Fig. 4).

(4.3) Integration of lighting with building structures

New and sometimes revolutionary methods of factory construction have enabled lighting engineers to design unorthodox installations in which the lighting is integrated with the structure. Examples are particularly numerous in the case of the " north sky " roof construction where the solid section of the roof acts as a huge light reflector. Bare tubes can be fixed to the lower edge, but refinements have been developed with parabolic reflector units controlling the light distribution so that the overall effect from direct and indirect lighting gives satisfactory working conditions (Fig. 5).

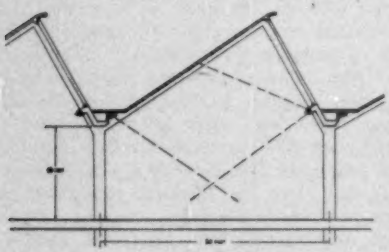


Fig. 5. (*Above*) *Integrated factory lighting with parabolic reflectors.*

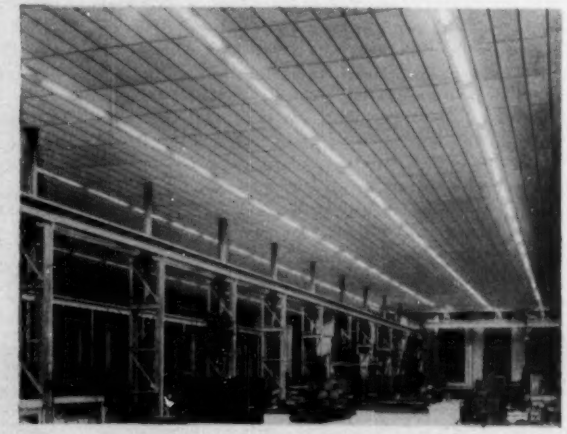


Fig. 6. (*Right*) *Industrial lighting recessed in ceiling.*

Lighting recessed into the ceiling is more common in commercial buildings, but there are some notable examples of engineering shops where this system has been employed (Fig. 6). This is, of course, a particularly useful and economical solution for those areas where flameproof equipment is required.

Some interesting barrel vault structures of shell concrete, like the rubber factory at Brynmaer, call for special lighting treatment, particularly where access to the lighting equipment has to be provided from the outside. One solution consists of a number of circular lay lights, some admitting daylight and others containing fluorescent tubes accessible from the outside.

(4.4) Maintenance

The importance of good maintenance in industrial lighting has been stressed in a number of papers before this Society[13, 14], but progress has been slow in establishing regular routines for cleaning and relamping. There are exceptions, such as food factories, where the whole factory including the vapourproof fittings, is regularly hosed down. Where cleaning is particularly difficult, as in foundries, self-cleaning fittings have been developed[4].

There has been some opposition to the use of fluorescent tubes for high bay lighting on the grounds of undue deterioration caused by dirt, but the reflector tube may well change the balance of advantages.

Group replacement of lamps ensures the maintenance of a satisfactory lighting level and the proper use of capital equipment, assists the budgeting of lighting costs and leads to substantial savings in labour costs. The higher labour cost of individual lamp replacement is now being appreciated by managements, and the establishment of maintenance contractors is an encouraging sign.

(5) Office Lighting

During the early years of the period under review, many factors combined to bring about substantial improvements in industrial lighting standards, but there was a slower rate of progress in office lighting. For some years after the war,

building licences were not granted for new office buildings, or even for their reconstruction. The installation of fluorescent lighting was at first subject to licence and was only permitted for factory use. In addition, fuel restrictions limited the use of lighting in offices during the winter months. All these obstacles to progress in commercial development were only removed in the early 1950s—building licences were required until 1954—and the last few years have witnessed the building of many office blocks incorporating new techniques of construction.

(5.1) Illumination levels

An interesting insight into the position in 1948 is given by one of the post-war building studies devoted to the lighting of office buildings([15]). It showed that between one third and one half of all types of work, other than in drawing offices, was carried out with an illumination level of less than 10 lm/ft², i.e., below the levels recommended by the I.E.S. Code. The report refers to a period when the fluorescent tube had made little impact in the commercial field, as three out of four persons questioned had incandescent lighting only. The report recommended 20 lm/ft² for most general office activities and 30 to 50 lm/ft² for drawing offices, values which are still accepted as satisfactory even today. It is noteworthy that the Office Regulation Bill of 1957 (Bill 29) lays down a minimum of 20 lm/ft² for offices and 30 lm/ft² for drawing offices.

Attempts to improve illumination levels after the war often consisted of merely inserting higher wattage lamps in existing fittings. This led to the overheating of glass diffusers, increased their brightness and gave rise to discomfort glare. Sometimes simple 80-watt fluorescent batten fittings replaced 75-watt or 100-watt lamps in age-darkened opal bowls. The result was a doubling or trebling of illumination level with unchanged electricity consumption, but the resulting glare gave rise to complaints about the harmful effect of fluorescent lighting.

The increasing mechanisation of office work has made adequate lighting essential. The lower ceiling height of new buildings favours the use of fluorescent tubes in ceiling-mounted or recessed fittings. Progress in the various branches of commerce has by no means been even : nor can this diversity be explained by the complexity of the tasks performed. Offices attached to factories were perhaps the first to have adequate illumination. Banks have appreciated the value of well-lit banking halls and have not only adopted satisfactory levels of illumination but have also initiated some of the more original and, at times, gaudy fittings designs. On the other hand, many city offices are still grossly underlit, though the need to attract staff, particularly typists, has rapidly led to some improvement in standards, as good lighting forms part of the pleasant and attractive working conditions required.

(5.2) Quality

The effect of increasing illumination levels in offices was often the creation of glare, both direct and reflected, which seriously reduced the value of the change. The prevalence, in this country, of 80-watt fluorescent tubes with a luminance of 4 cd/in² aggravated the effect.The use of industrial reflector fittings in offices brought some improvement and owing to price differences between industrial and commercial fittings, partly caused by Purchase Tax legislation, industrial fittings are still frequently used. A more general light distribution is, however, needed for offices, and fittings with diffusing side panels and with either louvres or diffusers at the bottom are now widely employed.

A louvre may cause reflected glare from shiny paper and the keys of office machinery, and the most careful positioning of light sources is easily made useless by a subsequent rearrangement of desks. Fortunately the manufacturers of typewriters are slowly being educated to the use of matt finishes which may eventually eliminate this awkward problem.

The threat of reflected glare is even more serious in drawing offices and may account for the persistent prejudice against the use of fluorescent lighting by draughtsmen. Satisfactory solutions have been found by the integration of lighting in the building structure ; this will be referred to later.

The choice of light sources is governed by both financial and functional considerations. Where first costs are important, tungsten filament lamps or fluorescent tubes with ballast lamps are favoured unless the period of usage makes orthodox fluorescent lighting obviously more economical. In Government offices, for instance, fluorescent lighting is often employed on the darker lower floors, with incandescent lamps in opal glass fittings in other areas.

(5.3) Built-in lighting

Whilst the majority of office installations employ suspended fittings, low room height and the growing tendency towards the incorporation of many services behind a false ceiling have also influenced lighting design. Suspended fittings tend to make a low room appear still lower ; many new buildings

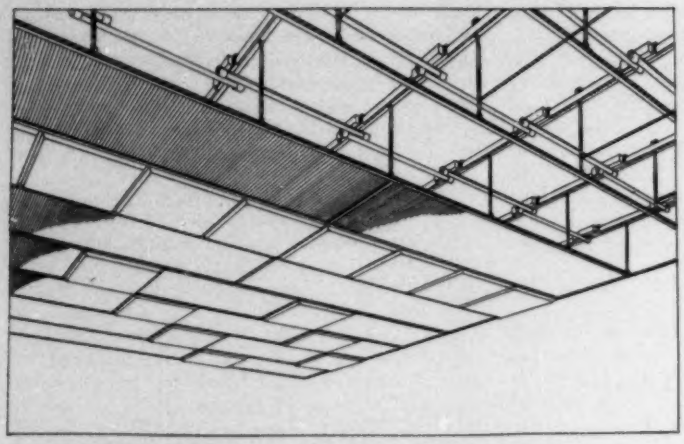


Fig. 7. Modular grid ceiling with vinyl foil diffusing panels.

Fig. 8. Flexible office lighting with commercial trunking.

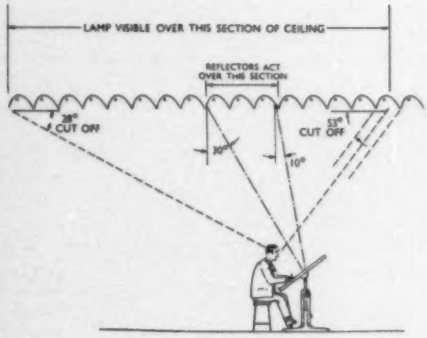


Fig. 9. Drawing office installation with special ceiling design.

therefore incorporate the so-called "troffer" fitting. Such a fitting contains up to four fluorescent tubes and is mounted flush with the false ceiling. Early fittings of this type necessitated the cutting of an accurate rectangle in the ceiling to admit the fitting, but recent designs are dimensioned to take the space of one, two or more ceiling panels and thus are easily incorporated in the structure. Individual fittings may be as large as 8 ft. by 2 ft. in size and continuous lines can extend down the whole length of a room. If the troffers are suspended from the true ceiling, special adjustments are provided so that they are accurately located in the false ceiling.

Metal or plastic louvres were generally used in troffer fittings but caused reflected glare in some cases. The wider light distribution and greater efficiency of acrylic diffusers, coupled with the possibility of directing more light back on to the ceiling have made this type of diffuser a more popular choice in recent years.

The logical development from the troffer installation is a ceiling which is itself the light source. In the United States various versions have been widely applied, first the all-louvred ceiling and later the luminous ceiling. The levels of illumination obtained are very high, considerably higher than the standard generally attained in this country, but the extraordinary uniformity of illumination results in a degree of monotony which is considered by many to be undesirable for large areas. This objection can be overcome in

other systems (developed in the U.S.A. and introduced in this country during 1957–58) in which a metal grid holds square diffuser panels of vinyl foil which can be coloured, patterned or opaque, thus creating distinctive variations in ceiling appearance. (Fig. 7.)

Modern office design aims at flexibility, and partitions are designed so that they can be easily moved. For commercial buildings shallow trunking systems have been developed which carry the electrical services. Lighting fittings are suspended from this trunking, capable of removal to other positions without the need for re-wiring. (Fig. 8.)

Interesting lighting installations have been devised for drawing offices, where the whole ceiling is designed to act as a light reflector. In one recent example continuous lines of ceiling fittings have been installed at 3 ft. centres with a series of baffles mounted on the underside of the ceiling designed to give a 20 deg. cut-off. The illumination level is 60 lm/ft^2. In another drawing office the ceiling has been transformed into a number of parabolic reflectors designed to give satisfactory cut-off and to prevent any light being reflected back into the draughtsmen's eyes. (Fig. 9.)

In the 1940s the phrase " built-in lighting " probably conjured up the idea of indirect lighting from cornices. This method still finds application in high banking halls and municipal buildings, and if the ceiling design is such as to act as a light reflector the overall lighting can be quite adequate. The complete uniformity, however, and the fact that the ceiling is the brightest area, renders such an installation somewhat unsatisfactory. Frequently there has been a demand for additional desk lights from the staff even though there is no lack of light.

It is surprising that there has been so little experiment with built-in directional lighting. A very early example was the drawing office at the " Britain Can Make It " exhibition of 1946 which was illuminated from a large false window containing banks of fluorescent tubes. Baines strongly disapproved of this idea which, in his view, produced an effect " as dead as a glass eye "([16]), but the report of the National Illumination Committee([12]) refers to a factory installation of this type as highly successful. A few examples of this kind of lighting have been reported, one being an entrance hall lit from behind venetian blinds at clerestory level (Fig. 10). It would appear that there is scope for further experiment in this field.

(6) Shop Lighting

In post-war years there has been a rapidly growing appreciation of the importance of good lighting for selling, with the result that the lighting of shops and stores has made phenomenal progress. In the immediate post-war years the lighting of shop premises was restricted to 1.5 watts per sq. ft.; shop windows could not be lit at all. Using 150-watt tungsten filament lamps the average illumination could therefore be only in the region of 3.5 lm/ft^2 though it was possible to

Fig. 10. Office entrance lit by fluorescent tubes behind venetian blinds.

achieve about 6.5 lm/ft² with the fluorescent tubes of that time. The restrictions were eased in 1949 and finally removed in 1951 and illumination levels rose rapidly.

The consistent modernisation policy for many large stores and shop groups in which lighting plays a substantial part is evidence that good lighting pays. Since the war shop lighting development has seen four stages—namely :—

(1) Fluorescent lighting only, under fuel restrictions ;
(2) Fluorescent lighting after the removal of restrictions ;
(3) The reaction against fluorescent lighting and a return to tungsten filament lamps ;
(4) The combination of fluorescent tubes and tungsten filament lamps.

There is, of course, no clear historical division. Some shops never used fluorescent lighting, others are still content with this light source alone ; combined systems were advocated as early as 1947.

The function of lighting is different for shops, departmental stores and chain stores : so different, in fact, that developments in the last 10 years have taken separate courses. It will therefore be advisable to investigate the three categories separately.

(6.1) Departmental stores

Departmental stores have been described as a combination of speciality shops under one roof, but they lack some of the advantages of the speciality shop—intimacy of scale and concentration on one product. Although an attempt is often made to split the store into smaller and reasonably self-contained sections, the ceiling is common and so, with a few exceptions, is the lighting[17].

As the position and arrangement of departments may change from time to time, the first requirement is a general system of lighting with considerable uniformity. The level of illumination has risen from 5 to 8 lm/ft² before the war[18] to 25 to 40 lm/ft² today. At first, fittings using two 80-watt fluorescent tubes were employed, with the result that the store ceiling became over-crowded. Larger units with four or six tubes were developed and at the usual suspension height they provided a reasonably high level of illumination, but with a lack of variation and shadows. This has laid the lighting open to the criticism that it created a " morgue-like atmosphere "[19].

The need for highlights to overcome this feeling of monotony and to attract attention to specific displays was met by the provision of adjustable spotlights which, in some cases, caused a veritable rash of lights—some dangling from the ceiling, some sprouting from walls and others even stretching out from the fluorescent fittings. In some stores incandescent lamps have been incorporated in the lighting fittings between and even behind the fluorescent tubes. The result has been a considerable increase in electricity consumption, some improvement in colour rendering, but very little livening up of the general appearance (Fig. 11).

The development of fluorescent tubes with good

Fig. 11. Store lighting installation with four 5 ft. 80-watt fluorescent tubes and two 60-watt incandescent lamps per fitting.

Fig. 12. Decorative cold cathode lighting in a London store.

colour-rendering properties, together with the growing appreciation of the important and beneficial part which a suitable colour scheme for ceiling and walls can play, has done much to help display managers. Natural, White and Warm White tubes are now widely used and some stores use a combination of two or three tube colours to give the best results.

Cold cathode tubes had a period of ascendency in the 1940s and the three-tube ceiling unit was a familiar sight in a number of stores. A growing aversion to bare tube fittings of any kind and the increasing advantages of the hot cathode tube have, however, diminished this appeal very considerably. One of the more recent cold cathode installations uses special large area fittings 16 ft. in length, with decorative glass diffusers (Fig. 12).

(6.2) Multiple stores and supermarkets

The multiple store and supermarket are designed to induce the passer-by to enter and to tempt him (or rather her) to purchase goods on impulse. The arrangements of counters and displays, and also the lighting, combine to achieve this result. There must be plenty of light. An illumination level of 40 lm/ft^2 in the early 1950s was far above common lighting practice, but since then levels have increased until now there are examples of 60 lm/ft^2 and even 80 lm/ft^2. There is no doubt that the brighter appearance constitutes a considerable sales appeal in this kind of store.

Some multiple stores have adopted multi-tube louvred fittings, similar to those employed by departmental stores but others are boldly exploiting the attraction of light by using continuous runs of light from the front to the back of the store.

Twin 80-watt fittings with diffusers are common with one group of stores, whilst another, after using three or four runs of 40-watt tubes, has now changed over to twin and triple runs of bare 8 ft. tubes (Fig. 13). In addition there is concealed lighting around the perimeter, in wall cases and other displays.

Tube colour has formed the subject of careful investigation and as a result one group of stores uses exclusively Natural, another 3,500 deg. White, a third Warm White, and yet another mixes Natural and de Luxe Warm White. This may be explained by the subjective nature of colour response, but there is also some indication that, at the high levels of illumination encountered in large stores, minor colour deficiencies are less noticeable than at lower levels.

The lighting of refrigerated food displays has, however, remained a problem, not only because the colour of meat may be distorted, but also because certain foods discolour within a short time when exposed to light of any kind.

It is not surprising that tungsten filament lamps have made relatively little headway in multiple stores, for there is no obvious incentive to highlight particular products. However, there are indications that the use of spotlights is growing.

(6.3) Shops

Whilst there is some consistency of character in departmental and multiple stores, shops vary widely in size, position, range of products and

Fig. 13. Triple runs of 8 ft. 125-watt fluorescent tubes in a multiple store at Oxford.

also in the type of customers. On the one hand there is the small suburban hardware shop or tobacconist in which, perhaps not so very long ago, the unshielded 60-watt lamp was replaced by an 80-watt fluorescent batten fitting ; on the other hand, in a fashionable shopping area like Bond Street, London, each shop seeks to outdo its neighbour in the novelty of its display and the ingenuity of its lighting. It has been a fascinating experience to watch the ideas developed in the West End gradually spreading to the suburbs and to the provinces, often because the suburban branches of large groups have made local changes in shop appearance and lighting.

During the immediate post-war years commercial fittings with one or two 80-watt fluorescent tubes were the rule for shops. Even today, a large majority of shops are lit in this manner though there is a growing tendency towards tungsten filament lamps for special displays.

As a reaction against the wide use of fluorescent lighting some " exclusive " shops employ incandescent lamps only, sometimes in period chandeliers, sometimes in contemporary glass or metal fittings. The speciality shop offers the greatest scope for original design, and shoe shops have been prominent in the successful use of lighting systems which have been completely integrated in the interior design. It will be useful to examine various methods of integration in more detail.

(6.4) Integration and flexibility

In shop design, much more than in industry and office projects, aesthetic considerations are of primary importance. Shop lighting has therefore become increasingly the domain of the specialist architect and designer who is often reluctant to use self-contained fittings but who is anxious to exploit ceilings, walls and other structural elements in the lighting design.

The simplest form of built-in lighting is the use of troffers in suspended ceilings which has already been described in Section 5.3. This has found application in medium sized shops where a business-like utilitarian effect is intended. Considering the advantages of higher mounting height, it is surprising that this system has not had a wider appeal.

Luminous ceilings of various kinds have been employed. First the louvred metal version, followed by clear or opal plastic louvres. Corrugated vinyl foil sheeting has proved particularly useful in car showrooms where it eliminates the reflected images of light sources.

Luminous ceilings have not, so far, been much employed for the lighting of large showroom areas, partly, no doubt, because there is a danger of monotony from a uniformly bright ceiling. A grid system with panels of vinyl foil providing a change of brightness and texture (see Section 5.3) may be expected to prove useful to shop and store designers in the future. A luminous ceiling with a difference is seen in Fig. 14 where incandescent spot lamps are directed on to a folded ceiling, producing a regular but interesting pattern of light and shade.

In contrast to the lighted ceiling, there has been a considerable vogue for dark ceilings. It is claimed that as bright ceilings or fittings attract the eyes

upwards away from the merchandise on sale, so a dark ceiling will concentrate attention on the sales area. Porthole type display fittings can be used to produce a " starry sky " effect. The danger of excessive contrast has been overcome by suspending batteries of small fittings at a low level and directing some light on to panels below the ceiling (Fig. 15). Another kind of dark ceiling—the so-called " Rotterdam " ceiling—will be discussed later.

Some of the most successful lighting installations are those in which the treatment of the ceiling is related to the design and purpose of the areas underneath. Fig 16 shows an installation in which fluorescent tubes are concealed in the perimeter and behind the false ceiling panels, whilst the main ceiling area is dark and contains a number of spotlights. The ceiling may even become an important decorative element in its own right with built-in highlights and areas of shadow and half-light (Fig. 17). There is, however, a temptation in this decorative use of light to create a degree of restlessness which is likely to " date " an installation very quickly. It is perhaps not only for economic reasons that some recent installations show a reaction against the dramatisation of lighting, and a return to simpler shapes.

In the speciality shop, the lighting once installed is likely to remain satisfactory as long as the general design of the shop does not change. In the departmental store, on the other hand, frequent changes in floor layout are a matter of routine and the lighting must provide for this. If an installation aims at more than general illumination, it must be flexible so that it can be adjusted to changing needs.

One such system was first introduced in a store at Rotterdam and is therefore often called the " Rotterdam ceiling " ; it consists of a grid of modular design suspended below the true ceiling. Troffer fittings designed to rest on the grid and electrically connected by means of plugs can be moved to other grid positions with little difficulty. In order to disguise the ceiling and its services, all pipes, the ceiling itself, and frequently the grid, are painted in dark blue or black. This grid system has been used successfully in some installations in this country, although there is considerable opposition to the large area of darkness and its contrast with lighting fittings. An installation of this type is shown in Fig. 18, though there is some doubt whether the fittings have, in fact, been moved since the completion of the original installation. It is likely, however, that once the ease of changing is appreciated by store managers flexible lighting will prove acceptable.

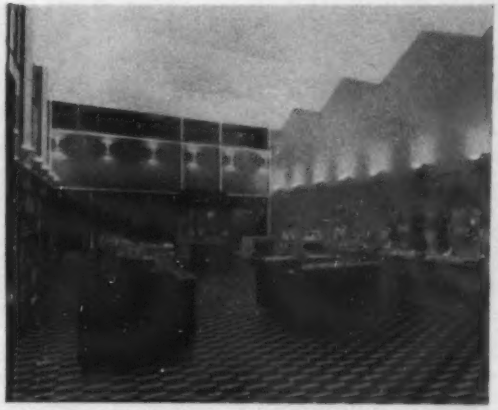


Fig. 14. Indirect lighting of folded ceiling by incandescent lamps.

Fig. 15. Direct lighting with dark ceiling relieved by throwing light on to floating panels.

Fig. 16. (*Above*). *Combined fluorescent perimeter lighting and incandescent down-lights.*

Fig. 17. (*Top right*). *Lighting forms decorative ceiling pattern in this shoe shop.*

Fig. 18. (*Bottom right*). *Dark grid ceiling with flexible lighting.*

(6.5) Display window lighting

After the removal of the ban on window lighting in 1949, few shopkeepers resisted the temptation to celebrate the end of the black-out by installing some lighting. This consisted all too often of bare fluorescent tubes framing the window, but it was soon discovered that although bare tubes attracted people to the windows, they made it difficult for them to see the displays without discomfort. In better shops the tubes were soon shielded either in parabolic reflectors or behind baffles or louvred ceilings.

A new technique of window lighting had to be evolved when it became obvious that the use of fluorescent tubes alone creates a flat uninteresting effect. Thus tungsten filament spot lights were added, often with fluorescent lighting for the background which could be made " alive " by colour change[20].

The closed back window with a " picture frame " offers the greatest possibilities from the lighting point of view, as the frame conceals the lighting equipment and allows the installation of batteries of fittings. In contrast to the picture frame window, island windows can be viewed from many angles and the concealment of the light sources has proved very difficult. In practice the louvred ceiling has been accepted as the best compromise ; the light sources are hidden but the result is often flat.

The illumination level for window displays is generally at least twice that in the shop itself and levels of 50 to 100 lm/ft² have become common for ordinary shops and 100 to 200 lm/ft² in main shopping centres. Some large stores have recently introduced a mixture of 125-watt fluorescent mercury lamps and 300-watt tungsten filament lamps, with which they achieve between 300 and 500 lm/ft².

Although illumination levels have risen, the main concern has been the improvement of modelling, the heightening of dramatic effect, and versatility. The introduction of low voltage spotlights for highlighting small areas may well prove of considerable importance in this connection.

The colour of window lighting has caused concern in the past, particularly in departmental stores where the merchandise exhibited in any window may change from month to month. Colour-mixing circuits have been designed to provide flexibility in the colour of windows[20] and have already been adopted by a number of stores.

(7) The Challenge of the Future

Our investigation of lighting developments in the post-war years has established some common trends and some potential conflicts. The increased importance of artificial lighting has been widely appreciated and has led to a considerable increase in illumination levels. In this the fluorescent tube has played a leading part. The opportunity created by new building techniques for integration of lighting with the structure has been exploited in many installations.

On the other hand, the qualitative aspect which has had so much theoretical attention in recent years has made little progress except in display lighting. This may be explained by the fact that, for many visual tasks, a higher level of illumination in itself means also an improvement in quality. A further reason, however, has been the overriding concern for flexibility which has made it impossible for lighting engineers to plan a static layout. The demand for flexibility is common to all activities, and lighting design must either be adaptable to changing conditions or provide virtually uniform lighting. This problem has been successfully solved by the use of industrial and commercial trunking and some tentative solutions have been found in store lighting.

There is an apparent conflict between the requirements of quantity and quality and between the trend towards integration and the demand for flexibility, a conflict in which lies a challenge for the future. The designer of lighting equipment and installations must realise the changing needs of modern society and be aware of the possibilities and limitations of present-day building and furnishing. Lighting research must find a bridge between the leisurely world of mathematical exercise and laboratory experiment, and the practical problems which face the harassed lighting engineer.

The architect and interior designer must be encouraged in their growing appreciation of the vital part that lighting can play and of the great contribution that the experienced and imaginative lighting engineer can make. It is the very existence of these conflicting trends and requirements which force the architect, lighting engineer and the user of lighting equipment to work together and thus hold out the promise of future progress.

Acknowledgments

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Discussion

Mr. JOHN REID: I find that I have nothing to disagree with in this paper, but I think it is a very good thing to stop and take stock occasionally to find out just where we have got to. It is now about ten years since we really started developing modern lighting and we have come a fairly long way, especially when you think of all the things that have happened. In 1948-9 people could not be too fussy and, in fact, were only too happy to get a fitting at all. We then went through a period of shortages, and until 1954, when restrictions finally disappeared, everything was make-shift. During that time lighting engineers were learning a great deal and we went from the simple tungsten fittings we had before the war to the more complex fittings we now use in our illumination schemes. We have now reached the stage where we have found that there is no one solution to the lighting problem. All light sources have a legitimate part to play and can be used with imagination to produce exciting lighting schemes. The lighting industry should be proud of the work done over the past ten years; but your job is only just beginning. Dr. Ballin has talked about integration and showed slides which are accurate and fair, and a good selection of what most interiors in our cities look like today; and they show what an abysmally low standard exists. The unfortunate thing is that lighting equipment is so far ahead of the users of lighting that it makes one grieve.

Most of our stores are beautifully lit and the lighting installations we have are, on the whole, quite good; but the stores themselves are desperately poor in design.

We have lighting ideas, but we have not got the interiors in which they can be used. The reasons for this are, firstly, the war, and the subsequent restrictions on building. There are notable exceptions, such as schools, but most of our present-day buildings were either designed during the war or were commenced immediately after the war, and are pre-war in their design and layout. But now, on the drawing boards, we are reaching the point where really exciting buildings are coming along; buildings where the lessons which have been learned are beginning to be used. The lighting is not just tacked on to buildings, but is now becoming part of the structure. So far, you have had to deal with ordinary buildings but in the future architects are going to come to you with far greater demands.

It is a pity that with the amount of work the lighting industry puts into its equipment, it does not do more to build up a corps of imaginative, forward-looking lighting engineers. The number of good lighting engineers in this country can be counted on the fingers of one hand.

I repeat that I can find nothing to disagree with in Dr. Ballin's paper. To me the survey is a fascinating one and a promising one and I look forward to many interesting developments in the future.

Mr. L. C. RETTIG: Dr. Ballin's review of industrial lighting is an excellent guide to future developments in this field, and it is appropriate that he should refer to the miserably low standards

which are all legislation demands. Most of us are well aware that the illumination values laid down as a minimum should be doubled, at least, for any factory, and the impossibility of carrying out any task with reasonable efficiency at a level of 6 lm/ft² has been ably shown in the paper.

The author also refers to the higher illumination levels now coming into use. Much of this progress is attributable to American influences in the branches of American undertakings set up here. not necessarily by better techniques but by the demand for levels of illumination more common in the United States.

(As an example of this development and to show how transverse louvring, of which Dr. Ballin had said few installations were extant, had been considered, Mr. Rettig showed two slides of a new factory in Scotland with an illumination value of 80 lm/ft² by 8 ft. 125-watt tubes on trunking. The reflectors were continuous and the louvres provided a cut-off of 20° only, an angle deemed to be quite sufficient for brightness control in industrial interiors where the overall efficiency is also a consideration.)

Mr. A. H. Olson : I am afraid I am going to start off with a point of criticism—surely Dr. Ballin should have illustrated the paper with colour slides and not black and white. Colour does improve the picture out of all proportion.

I would like to take up the point made by Mr. Reid in regard to the new buildings both in the United States and Europe which have made their appearance in the last few years, producing futuristic shapes which have resulted from suspensions, cantilevering and counter-balanced masses. These techniques have arisen out of the advent of new materials and fresh thought, offering the lighting engineer a challenge for the future. Building design is no longer the prerogative of the architect, for the constructural engineer has come into his own.

I must say something in defence of shop and store lighting. Since the war we have had a Scandinavian trend and then an Italian trend. Now we have a Japanese influence in speciality stores, resulting from the American occupation of Japan. When you're talking about stores it's all very well to say you will put this and that in, but you are caught up by economics. The first thing the proprietor says is—" This is my sales floor and my target is a sales turnover of, say, £50 per square foot." This immediately gives you some guidance to the lighting budget he has in view.

With the advent of the new lighting materials, such as plastics for backgrounds, we can look forward to new conceptions in lighting for the future.

Mr. W. Imrie-Smith : This isn't actually a criticism, but rather a desire to get into better perspective a point made by the speaker—and that is this question of integration. It has been our experience in lighting development that every time we have a new lamp or a new technique, we always totally misapply it, and seem to forget everything we have previously learned, before we find the correct way to use it. I feel that integration is practical in connection with many of the examples shown for commercial use, but that we have to be a little cautious when we apply it to industry, which is primarily concerned with utilitarian results. The speaker did say that perhaps we were travelling a little too far with the integration idea, and that supplementary lighting would be required. We have an analogy in the window and store lighting which he showed, where these wonderful lighting installations have been relegated to the background, and then supplementary lighting, either with spots or local lighting, is superimposed to get the effects required.

We have got to remember that the architect is faced with the problem of finding certain accommodation and making the best provision he can for natural lighting. Illuminating engineers know from experience that daylight is not always the best condition for seeing a particular job or operation, and in fact suitable artificial lighting is far superior to daylight in many cases. More emphasis has to be placed on making suitable lighting arrangements for the actual operations involved and whilst we can develop more detailed factors in connection with integrated installations, we will also have to install additional lighting for the operatives' needs.

I feel that in the future integral lighting will be merely background lighting, and that supplementary lighting must be superimposed, otherwise we are restricting ourselves to inferior results instead of controlling the lighting to meet the actual visual requirements.

Mr. S. Anderson : I would like to ask Dr. Ballin if he can justify the ratio which he gave us in connection with an economic point which I feel to be of considerable importance, and if it is justified, if he could indicate the basis of the statement. He said we could get fifteen times as much light for a penny as we could in the early 1940's. Whilst I am prepared to believe we can get considerably more light for our money I would

not have thought the increase was as much as that. If he can justify this, it seems a great achievement by the lighting industry in these times when things are increasing in cost so rapidly.

I would refer also to Fig. 3 in the paper in which it does not seem to me that the mounting height available is suitable for such a powerful light source. Could the author give us some idea of what the mounting height actually was for that particular installation? My own view is that the mounting height for such an installation of 1 kW discharge lamps should be not less than about 40 ft. from the floor.

Dr. J. W. T. WALSH: The previous speaker seems to have been misled by Fig. 1 where the cost of fluorescent lighting is shown as the cost of the lamp alone per lumen hour, without taking into account the cost of the power consumed. Misunderstanding might be avoided if the author could title the figure differently.

The author has made a good deal of the fact that standards of illumination have increased enormously during the last fifty years. He pinpoints this by comparing figures in the 1946 and 1955 I.E.S. Codes. We know that from a number of quarters the I.E.S. has been criticised by the uninitiated for the continuous rise in the figures given every time the Code is issued. Would it not be useful to anticipate such criticism by making it clear that there is a good technical reason for the increase in illumination levels; without any such explanation the author's remarks tend to invite such uninformed reflections on the soundness of the Code.

Mr. J. B. HARRIS: Being connected with a large organisation that views with suspicion any increase in lighting standards, I heartily agree with the last speaker.

Dr. Ballin said it was impossible for him to include every improvement, but I think there are two that could be mentioned. Mercury fluorescent lamps with internal reflectors, in 250- and 400-watt ratings, are being found useful in a number of fields. I have used the latter in conjunction with 500-watt tungsten reflector lamps with very good quantity and quality results. In section (2.4) reference might have been made to the reduction in physical size of certain general purpose tungsten lamps. I would also like to comment on the quality factor mentioned in (5.2), with particular reference to drawing office lighting, as I do not think that a reasonable answer has yet been found to this problem. In the drawing office having the special ceiling design illustrated in Fig. 9, the illumination levels were in the 80 lm/ft^2 region and this scheme must have been comparatively expensive. I have yet to discover a simple solution, however, in which fluorescent lamps only are used. It is not only a question of a reflected glare, as draughtsmen raise all sorts of other objections such as lack of shadows when they are desired, and presence of shadows where not required. I feel the only solution is the use of tungsten lamp bracket fittings for local board illumination and fluorescent lamps for overall room lighting.

With regard to the financial considerations affecting the choice of a light source, one reads many articles which deal in a general way with this subject. Since, however, so much depends on how much you pay for your fittings, the annual burning hours of the lighting scheme and the cost of electricity, the lighting engineer must make a detailed economic survey relating to his own particular project.

Mr. F. L. CATOR: At the last meeting of the C.I.E. which took place in Zurich in 1955, the South African National Committee on Illumination had the honour to be asked to take over the Secretariat on "Light for Selling." We in South Africa are therefore very interested in this paper by Dr. Ballin, particularly insofar as it deals with trends in shop lighting.

Since arriving in England I have had the opportunity of viewing the lighting installations in a number of shops and large stores in London and as a result I can say that the trend in Johannesburg is much the same as in London, particularly as regards the use of supplementary tungsten filament fittings in combination with fluorescent lighting.

However, there is one noticeable difference and that is the apparent absence in London of any large installations employing the 8-ft. 75-watt 1½-in. diam. "Slimline" lamp or the 8-ft. 105-watt 1½-in. diam. "Rapid Start" high output hot cathode lamp. There are some large installations in Johannesburg and elsewhere in South Africa, employing these two lamps. Personally I do not think these two American lamps have any advantages over the British 80-watt or 125-watt hot cathode lamps, when compared on a running cost basis, but I would like to ask Dr. Ballin for his comments.

It must be remembered that the lighting market in South Africa is much more competitive than in Britain. By that I mean that a lamp manufacturer in Britain has only to compete with other British manufacturers, whereas in South Africa

he also has to compete with American and European continental manufacturers. With this in mind I would suggest to British manufacturers that they become a little more aggressive in their export sales literature in regard to claims made for fluorescent lamp life, efficiency, lumen maintenance, etc., and that they keep a very close eye on what the Americans are doing in this regard.

Mr. A. WILCOCK : I would like to refer to the author's statement that the new reflector tubes may have some influence on design in the future. In my view the operative word is " will " and not " may " and I would go so far as to say that these tubes are making their impact now in the sphere of industrial and commercial lighting. Consider a batten fitting holding a reflector lamp equipped with a clip-on louvre. The lighting engineer may not like what he sees and it is a pattern perhaps not entirely to the liking of the fittings manufacturer. But the works electrical engineer can produce some telling arguments in its favour. The flux distribution is acceptable for most situations ; the lamp luminance is well under control ; the luminance distribution in the fitting's immediate vicinity (given reasonable decor) is in order. The most important argument, however, has to do with maintenance, which the works electrical engineer finds amongst the most difficult of lighting problems to solve. He will tell you that dirt has a minimum effect on his batten fitting, settling most heavily where he considers it to be least important. He will also point out that the reduced cleaning involved is more easily accomplished. The lighting engineer needs to be aware of the more subtle aspects of quality in lighting to win the day.

The author has not mentioned school lighting for the very obvious reason that it is impossible to cover all fields in detail in the paper. School lighting has, however, had a trend in the past ten years which is of considerable importance : I refer to the requirement of the 1944 Education Act in respect of daylight factor and particularly the 2 per cent called for in classrooms. Judging by the impressions conveyed by an architect in a recent paper to the Manchester Centre one of the features of post-war schools building has been the contortions to which architects and planners have been prepared to go to achieve what should not be a terribly significant feature of the natural lighting job anywhere—the provision of illumination. This is certainly not to decry the many virtues of natural lighting, but very briefly to state a case for a look at the overall economy of lighting embracing natural and artificial. In these days of cheap artificial lighting let us not lose sight of the very great field for artificial lighting development that exists in those situations where natural lighting is being used to provide illumination at the high expense of restrictions in building development.

Mr. R. BOISSEVAIN : The author says that the most significant changes over the last ten years have occurred in the design of fluorescent fittings. Whilst this is very true in connection with fluorescent control gear, surely the fittings have not changed so much in design, where one is limited by the length and shape of the tube. The tungsten lamp, for instance, has more scope and I would have thought the changes in tungsten lighting fittings were more significant.

THE AUTHOR (in reply) : With reference to Mr. Reid's introductory remarks, I would stress his emphasis on the need for variation in lighting. Apart from the science of lighting there is also the art of lighting. A really good lighting engineer needs plenty of imagination as well as technical knowledge.

Mr. Rettig pointed out the remarkably low levels in industrial lighting legislation. It is interesting to note that the Offices Regulations Bill, which unfortunately did not get farther than a first reading, specified very much higher levels of lighting. Mr. Rettig mentioned American influence ; there is no doubt that there are many factories which have based their lighting schemes on American levels and they have made substantial contributions to progress.

Mr. Olson said coloured slides would have been much better. I agree and had, in fact, selected some but there was no time to show them. He also mentioned the importance of economic considerations and I think we are all aware of this. I rather feel that he has been fortunate in shop lighting, where more money has been spent than in other fields.

Mr. Imrie-Smith may have misunderstood me a little. He talks about the relation of integration and supplementary lighting. Actually my point was that general lighting, quite apart from integration, may have gone too far. The point was that this was partly due to the demand for flexibility which makes it difficult to decide on " tailor-made " lighting.

I think Dr. Walsh has already answered in part Mr. Anderson's question on economics. I agree that the caption of Fig. 1 may lend itself to misunderstanding and will alter it. The point I meant to make is that the lighting industry had

done a good job of work in making lighting cheaper. In reply to Mr. Anderson's second question, the mounting height of the particular installation shown in Fig. 3 is 28 ft. and the illumination 25 lm/ft^2.

Dr. Walsh suggested that the reasons for the increased illumination recommended in the I.E.S. Code be given. This paper is not the place for doing this. To me the surprising thing about lighting levels is not that specified values have gone up but that the higher specified values have been so widely adopted, whereas ten years ago even the lower values were not accepted.

Mr. Harris draws my attention to certain omissions. I am interested to hear that the mercury discharge reflector lamp is widely used. I was not aware of that. He also referred to the reduction in size of some tungsten lamps which has mainly affected the domestic user. He asked about drawing office lighting and I suspect that he has been a little discouraged in his fight with the draughtsmen who insist on local lighting, nothing else, and maintain that the stroboscopic effect is serious. I feel that local lighting has its advantages but in our own organisation there are several drawing offices in which we have no local lighting and everybody is perfectly happy.

It was a pleasure to welcome Mr. Cator from South Africa. He raised two interesting points, in connection with the 8-ft. 75-watt slimline and the 100-watt V.H.O. tubes. In regard to the 75-watt slimline, this is only a continuation of the general American practice to use lamps with a low loading, whereas in this country the higher wattage lamp has proved more economical. A 125-watt lamp provides more light per £ of capital expenditure than the 75-watt type. For the same reason the experience with the V.H.O. here has been somewhat different from that in the States. We have the 5-ft. 80-watt lamp as a standard, which gives more light than the 100-watt V.H.O. In addition, the life of the V.H.O. is very much shorter. However, this is a development which needs watching and will eventually be of great interest for many specialised applications.

Mr. Wilcock refers to my statement that reflector tubes may have a great future. I agree that they are already making an impact, particularly in dirty surroundings—to which I refer in section (4.4). He refers to school lighting, which might well form the subject for another paper. I'm afraid I had to restrict the scope of my paper and it was not possible for me to include school lighting.

Mr. Boissevain feels that the changes in tungsten fittings design have been more significant. For the three aspects of lighting which I have reviewed, however, I consider the fluorescent tube has had a quicker and wider development but I would not deny the tremendous advancement in other fields, such as domestic and decorative lighting.

Report of the Council

January 1st—December 31st, 1958

The year was one of consolidation and preparation for the Society, lying as it did between adoption of the new constitution and the celebration of the Golden Jubilee. It has seen realised some of the fruits of work commenced in earlier years : the Transactions have been issued in a new and improved format ; the first Technical Report has been published ; the first Diploma Members have been elected under the new regulations ; the response to the call for increasing the membership of the Society has been rewarded by reversing the slight downward trend noted in the last two years. Against this background of heartening accomplishment, preparations for the Golden Jubilee celebrations have gone forward throughout the country in such a manner that in spite of the inevitable frustrations and delays 1959 should prove the most memorable of all the years in the history of the Society.

Early in 1958 Council considered how its work could be carried out more efficiently and economically and agreed that during the 1958/59 Session Council meetings should be held bi-monthly only. It is hoped that this arrangement will, without affecting the efficient administration of the affairs of the Society, make it possible for Council members, and Centres' representatives in particular, to attend all meetings. The General Purposes Committee will continue to meet monthly and to act for Council when necessary in the intervals between Council meetings.

For some time the staffing of headquarters has caused Council concern. Almost the whole of the executive work of the Society, including responsibility for the preparation of all its publications, has rested solely on the Secretary, assisted only by a small clerical staff. It is apparent that more satisfactory staff arrangements will have to be made in the future, bearing in mind the increasing amount of work handled by headquarters.

A Summer Meeting was held at Eastbourne during May and although the attendance was lower than at Harrogate in 1956 the occasion proved very successful and was, as always, most enjoyable.

1958 marked the 50th year of publication of *Light and Lighting* (formerly *The Illuminating Engineer*), and Council congratulates the Illuminating Engineering Publishing Co. Ltd. both on this event and on the present high standard of the journal. Although the Society is in no way involved in the policy governing publication of *Light and Lighting*, the welfare of the Society and that of the I.E. Publishing Company are interdependent and members in particular have benefited greatly from the progressive direction of the journal.

The finances of the Society remain sound. The year's operations have resulted in a small surplus of income over expenditure in spite of rising costs, and Council acknowledges its debt to the Honorary Treasurer for his planning and guidance. If, however, services to members are to be expanded —or even maintained should costs continue to rise—additional income is essential and this must come largely from increased membership.

At the end of the 1957/58 Session Mr. J. G. Holmes resigned office as Honorary Secretary and Mr. W. Robinson as Honorary Treasurer. Through years of exceptionally difficult and complicated work, Mr. Holmes and Mr. Robinson have guided the affairs of the Society well and enhanced the high tradition of service set by their predecessors. Council records its gratitude and appreciation to them and also thanks the retiring Vice-Presidents and members of Council for the work they have put in during their period of office.

Nominations additional to those made by Council to the vacancies for members of Council were received and a postal ballot was therefore necessary. The following officers and members of Council were elected and took office on October 1st :—

President:	Mr. C. C. Smith.
Vice-Presidents:	Mr. F. X. Algar, Mr. N. Boydell, Mr. H. G. Campbell, Mr. A. H. Olson, Mr. D. L. Tabraham.
Hon. Secretary:	Dr. W. E. Harper.
Hon. Treasurer:	Mr. A. W. Gostt.
Hon. Editor of the Transactions:	Mr. H. Hewitt.
Ordinary Members of Council:	Mr. E. S. Evans, Mr. J. T. Grundy, Dr. C. A. Padgham, Dr. A. Roberts, Mr. T. Roberts, Mr. W. T. Souter, Mr. D. A. Strachan, Dr. J. W. Strange.

The following were appointed to represent their respective Centres on Council for the Session 1958/59 :—

Bath and Bristol: Mr. D. E. Beard. *Birmingham:* Mr. L. E. Gibbs. *Cardiff:* Mr. F. H. Pulvermacher. *Edinburgh:* Mr. G. E. L. Comrie. *Glasgow:* Mr. L. C. Rettig. *Leeds:* Dr. D. L. Smare. *Leicester:* Mr. A. E. Bird. *Liverpool:* Mr. T. R. Jones. *Manchester:* Mr. J. D. Ducker. *Nottingham:* Mr. B. M. Cobbe. *Newcastle:* Mr. H. Ainsworth. *Sheffield:* Mr. K. Marshall. *Transvaal:* Mr. M. J. F. Dempster.

General Purposes Committee

The reduction in the number of Council meetings has inevitably thrown considerable additional work on the General Purposes Committee which is responsible to Council for all matters related to general policy, for finance and for liaison between the other standing committees. The Membership, Jubilee, and Summer-Meeting Sub-Committees of the General Purposes Committee deal with the relevant topics, reporting regularly to the parent committee. An additional sub-committee has now been appointed (under the chairmanship of Mr. J. G. Holmes) to deal with publicity.

During the year revision in the design of the Society's printed matter was completed and all the new certificates for Fellowship and Diploma Membership were issued.

Very few entries have been received in recent years from the younger members of the Society for the Silver Jubilee Award and on the recommendation of the General Purposes Committee Council has decided to discontinue the award. The Committee is now considering a new award to commemorate the Golden Jubilee ; the conditions of the award are not yet decided but it will almost certainly be given for outstanding services to lighting.

The last Report of the Council referred to the need for new headquarters premises. Although there is no doubt in the mind of the Committee that the need is urgent and that new premises must be secured very soon, it was thought best to leave the matter until preparations for the Jubilee were completed and Council has agreed to defer the matter.

Comment has already been made on the success of the Summer Meeting and Council records its thanks to Mr. H. G. Campbell for his services as chairman of this and the previous Summer Meeting Sub-Committee. In addition to Mr. Campbell the members of the 1958 Summer Meeting Sub-Committee were : Mr. N. Boydell, Mr. C. Dykes Brown, Mr. E. S. Evans, Mr. A. H. Nash, Mr. A. H. Young. It has been agreed that another Summer Meeting shall be held in the early summer of 1960 and Mr. J. G. Christopher has accepted nomination as chairman of the Sub-Committee.

The Jubilee Sub-Committee under the chairmanship of Mr. A. G. Penny has been in session throughout the year completing the detailed preparation for the many celebrations. Under its guidance local Jubilee Committees have been active in all Centres and as this Report is being written there is a sense throughout the Society of keen expectation. A well-attended Press Conference was held at the Criterion Restaurant in London on December 4 to introduce the Jubilee to the Press and similar meetings were arranged in several of the Centres at the same time. The members of the Jubilee Sub-Committee in addition to the chairman are : Mr. B. F. W. Besemer, Mr. H. G. Campbell, Mr. P. H. Collins, Mr. A. H. Olson, Mr. J. Reid, Mr. E. B. Sawyer, Mr. G. C. Small, Mr. W. R. Stevens, Mr. A. Wilcock.

The newly-appointed Publicity Sub-Committee has co-operated with the Jubilee Sub-Committee on publicity relating to the Jubilee and has produced the Jubilee Brochure. Designs for a Jubilee Symbol were invited and that submitted by Mr. Gordon House was selected from the large number received. The membership of the Publicity Sub-Committee is : Mr. J. G. Holmes (Chairman), Mr. J. J. Davies, Mr. D. W. Durrant, Mr. G. Reeves, Mr. G. F. Cole.

The following are members of the General Purposes Committee : The President, the immediate Past-President, the Vice-Presidents and Officers and two representatives of the Centres. For the 1958/59 Session the Centres' representatives are Mr. A. E. Bird, of Leicester, and Mr. D. E. Beard, of Bristol.

Membership

It is gratifying that the hard work put in by the Membership Sub-Committee of the General Purposes Committee and the Centres has now brought results. During the year approximately 260 applications for corporate and student membership were accepted and eight additional sustaining members were elected. These gains more than compensated the losses due to deaths and resignations, and the slight downward trend in membership discernible during the last two years has been decisively reversed, a net gain in membership of 74 being achieved.

It is most important that this upward trend in membership should be maintained and extended. The occasion of the Golden Jubilee will offer exceptional opportunities for recruiting new

Membership
(As at December 31, 1958)

	Fellows	Diploma Members	Corporate Members	Students	Total	Sustaining Members
London ...	100	99	560	35	794	64
Centres:						
Bath & Bristol	3	6	49	2	60	2
Birmingham ...	9	21	188	6	224	23
Cardiff... ...	3	7	40	1	51	1
Edinburgh ...	3	7	27	—	37	4
Glasgow ...	4	18	39	2	63	7
Gloucester & Cheltenham	—	—	19	—	19	—
Leeds	4	16	151	10	181	7
Leicester ...	3	6	42	—	51	1
Liverpool ...	2	4	108	2	116	7
Manchester ...	4	17	129	4	154	14
Newcastle ...	4	7	86	1	98	5
Nottingham ...	3	4	60	2	69	1
Sheffield ...	3	5	46	3	57	1
South Africa ...	1	3	59	—	63	15
Groups:						
North Lancs. ...	2	3	27	—	32	1
Stoke-on-Trent	—	—	16	—	16	—
Swansea ...	—	—	18	—	18	—
Tees-side ...	—	—	13	—	13	—
Overseas ...	11	18	231	—	260	1
Total ...	159	241	1,908	68	2,376	154

members and Council is anxious that these opportunities be seized. The decision that annual subscriptions to the Society will rank for relief of income tax means that where the full rate of tax is being paid the actual payment by Corporate Members will now be little more than £2, and for this members are receiving very considerable services. The new brochure on the Society has proved of considerable interest and value; a new printing has been called for and the opportunity has been taken to make minor corrections and to bring the brochure up to date.

It is not widely realised how many members of this Society reside overseas; at the present time it is more than 300 and there are members in every continent.

Council learned with great regret of the death on August 4 of Mr. H. Guy Campbell, Senr., a loss made more poignant by the knowledge that a little more than a year later his son would come to the Presidency of the Society which he himself had served from its inception. It is difficult to estimate the debt the Society owes to men such as Guy Campbell who guided its fortunes through the early years and whose help was always available to those in office.

The constitution of the Membership Sub-Committee for the current session is: Mr. D. W. Durrant, Mr. A. W. Gostt, Mr. J. G. Holmes, Mr. D. E. Mutch (Chairman), Mr. A. H. Nash, Mr. E. B. Sawyer.

Fellowship and Diploma Board

During 1958 Council approved the recommendation of the Fellowship and Diploma Board that Mr. J. W. Binns, Mr. C. J. Chisholm, Dr. A. Dresler, Mr. E. A. Langsdon, Mr. A. H. Olson, Mr. P. Petherbridge, Mr. H. R. Ruff and Mr. A. H. Young be elected Fellows of the Society. Council also approved the election of six Diploma Members

under the old regulations (the last group to be elected under these regulations) and five under the new regulations.

Council hopes that Sustaining Members and other employers will recognise the technical standing of Diploma Membership of the Society and will require applicants for technical appointments in lighting to have this qualification.

Awards Judging Committee

The high standard of several of the papers eligible for the Leon Gaster Memorial Premium made the task of the Awards Judging Committee particularly difficult this year. The Committee eventually recommended to Council that two awards of equal merit be made—to Mr. E. S. Calvert for his paper entitled " The Theory of Visual Judgments in Motion and its Application to the Design of Landing Aids for Aircraft," and to Mr. J. Gordon Scott for his paper " Lighting and Safety in Building Operations and Works of Engineering Construction."

Once again no entries were received during 1958 for the Silver Jubilee Commemoration Award and, as reported earlier, Council has decided to discontinue this award.

The members of the Awards Judging Committee for 1958 were : Dr. H. H. Ballin, Mr. N. Boydell, Mr. P. H. Collins, Mr. H. Hewitt, Mr. A. G. Penny, Mr. W. R. Stevens, Mr. J. M. Waldram.

Technical Committee

This has been the first full year of the newly constituted Technical Committee and has been a very busy one for the working panels.

The panel dealing with lighting in hazardous and corrosive situations completed its work and its report was published in November as I.E.S. Technical Report No. 1. This report was designed, as its successors will be, to complement the I.E.S. Code. In this way it is hoped to build a body of technical literature covering many facets of lighting that will help the practising lighting engineer. Many of the reports, including this first report, will be of value to a large number of people whose interests lie outside the lighting industry, and every effort should be made by members to ensure a wide circulation. This is one of the ways in which the Society is serving the community at large.

The Lighting Design Data Panel has produced an interim report entitled " Lighting Design—the Next Step " in which it recommends adoption of the Jones-Neidhart Zonal Method for calculating coefficients of utilisation. It does this to improve the accuracy of illumination calculations and to provide a link with luminance design. As the proposals of the panel require manufacturers to supply photometric data of fittings in a form rather different from that at present it was felt wise to discuss the interim report at a meeting of the Society before a final report is drafted. This discussion took place at the December sessional meeting and the comments made are now being considered by the panel.

Two new panels of the Technical Committee have been set up during the year. The first, under the chairmanship of Mr. A. H. Young, is to study the lighting of building sites and works of engineering construction and is the outcome of suggestions made during discussion of the paper by Mr. J. Gordon Scott in March. This is a good example of how the Technical Committee is able to meet an urgent need for authoritative information on new lighting problems.

As indicated in the 1957 Report of the Council the work of the Code Committee has now been brought under the authority of the Technical Committee. During 1958 the Committee established a Code Panel under the chairmanship of Dr. W. E. Harper to revise the I.E.S. Code. It is likely that the revision will be extensive and will include critical examination of the new codes published in Australia, the U.S.A. and the U.S.S.R. Four working groups have been set up to consider different aspects of the revision and it is hoped that the new code will be available during 1960.

Liaison with universities and technical colleges has been promoted by the Technical Committee and valuable exchange of views has taken place with the University of Sheffield, the Northampton College of Advanced Technology and the Bradford Institute of Technology regarding research projects for students.

In view of the heavy commitments of the Honorary Editor it was felt unreasonable to expect him to edit the Technical Reports of the Society and Mr. J. G. Holmes has agreed to undertake this work.

The membership of the Committee for the 1958/59 Session is : Mr. W. T. F. Souter (Chairman), Mr. N. Boydell, Mr. A. W. Gostt, Dr. W. E. Harper, Mr. P. Hartill, Mr. J. G. Holmes, Dr. R. G. Hopkinson, Mr. W. Imrie-Smith, Mr. J. S. McCulloch, Mr. A. Pott, Mr. W. E. Rawson-Bottom, Dr. A. Roberts, Mr. W. Robinson, Mr. H. R. Ruff, Mr. E. B. Sawyer, Dr. J. W. Strange, Mr. D. L. Tabraham, Mr. J. M. Waldram, Mr. H. C. Weston.

Papers Committee

Although sessional meetings of the Society are

held only from October to April, the work of the Papers Committee never ceases throughout the year, for even before the programme for one session is completed that for the next must be started. When, as in the present year, papers must also be prepared for a Summer Meeting, the work of the Committee is onerous indeed and Council records its warm appreciation to all members of the Papers Committee for the time and effort given. In particular it would thank the Honorary Editor of the Transactions whose task grows more exacting each year.

Reference has been made to the high standard of the papers being presented to the Society and this can be attributed in no small degree to the strict rules now applied by the Papers Committee to all contributions. It is an interesting fact that this policy has not reduced the number of papers offered. There remains, none the less, a need for more papers and the Committee is taking steps to encourage potential authors.

The new format of the Transactions has been well received and the Society can be proud both of the content and presentation. One further improvement is, however, required before satisfaction can be complete ; arrangements are needed to ensure some uniformity in the lettering of diagrams which at present range from the use of stencils to highly individual freehand efforts.

For some time Council has received criticisms that the Transactions not infrequently contain papers which can be appreciated by only a small number of members. While there has been undoubted truth in this assertion, Council has always felt it most important that such advanced contributions should be published by the Society not only to provide a record but also because of their potential importance to lighting practice of the future. Following recommendations made by the Papers Committee, Council has now agreed to meet these somewhat conflicting demands by instituting a monograph service. In future, therefore, papers dealing with highly specialised subjects will be published as " I.E.S. Monographs " at a price of five shillings. It is expected that the first Monograph will be issued early in 1959.

Council is confident that members will appreciate the extensive service now offered them in the Society publications and will give their full support.

It has been necessary throughout this year to hold sessional meetings in a number of places, and arrangements are now being sought by which all meetings, with the exception of the opening meeting and the Trotter-Paterson Memorial Lecture, are held in one place which will become the " home " of the Society.

The following were members of the Papers Committee at the end of the year : Mr. W. R. Stevens (Chairman), Dr. H. H. Ballin, Mr. H. G. Campbell, Mr. J. B. Collins, Mr. J. B. Harris, Mr. D. H. Holloway, Mr. T. Roberts, Mr. D. A. Strachan.

Education Committee

The outstanding feature of the year's work by the Education Committee was undoubtedly the one-day Conference on Industrial Lighting held at the Northampton College of Advanced Technology in April. This conference was attended by about 200 senior engineers and managers drawn from many industries and was opened by Mr. R. Bramley-Harker, H.M. Deputy Chief Inspector of Factories. Short lectures were given by Mr. H. Hewitt, Mr. W. R. Stevens, Mr. W. Robinson and Mr. J. G. Holmes and were followed by discussions in which these professional lighting engineers were confronted with problems raised by the users of lighting. In addition to the lectures a film was shown and the conference concluded with a " Forum." This was a new venture by the Society and its outstanding success suggests that similar conferences should be organised in the future to cover other aspects of lighting. Council is very conscious that a large amount of the credit for the excellent organisation of the conference should go to Dr. C. A. Padgham and records its thanks to him and to the college authorities for the facilities made available to the Society.

Consideration has continued of possible changes in the syllabuses for the City and Guilds of London Institute examinations, but the committee is not yet ready to report.

In the 1958 examinations held by the City and Guilds Institute there were 20 successes in the intermediate grade, 11 in papers 1 and 2 of the final grade and 13 in papers 1 and 3. These figures are considerably less than those of the previous year and Council hopes that all employers will encourage students to prepare for these examinations, for only so can the future supply of qualified lighting engineers be ensured. The Education Committee will continue to consider ways and means of making possible adequate preparation for the examinations, particularly in provincial areas where the number of students is too small to permit the organisation of conventional courses at technical colleges.

Lectures to schools have continued in London and a number of Centres and should reach a record number in Jubilee year.

BALANCE SHEET 31st DECEMBER, 1958

1957 £		£ s. d.	£ s. d.	1957 £		£ s. d.	£ s. d.
	Capital Account:				**Quoted Investments, at Cost:**		
	Balance at 31st December, 1957	8,085 4 10			£2,320 14s. 7d. 3½% War Loan	2,364 3 6	
	Add Investments transferred from International Illumination Congress Fund	404 8 6			£500 3% British Transport Guaranteed Stock 1978/88	488 4 6	
	Excess of Income over Expenditure for the Year	37 16 3			£500 3% Savings Bonds 1955/65 ..	501 15 3	
	Reduction in provision to reduce investments to market value ..	90 11 6			£1,000 3% Savings Bonds 1965/75 ..	1,000 0 0	
					£500 4½% Conversion Stock 1962 ..	500 0 0	
4,550				4,550		4,854 3 3	
8,085			8,618 1 1		*Less* Provision to reduce to Market Value	1,278 3 3	
	Reserve for Special Expenses:			1,369			
91	Balance as at 31st December, 1957 ..		91 7 8	3,181			3,576 0 0
					Unquoted Investments, at Cost:		
736	Creditors		990 17 6		£250 5% Defence Bonds	250 0 0	
					£1,250 4½% Defence Bonds	1,250 0 0	
					£1,100 3½% Defence Bonds	1,100 0 0	
					£1,250 3% Defence Bonds	1,250 0 0	
					£500 Abbey National Building Society ..	500 0 0	
4,250							4,350 0 0
76					**Debtors**		166 14 6
1,405					**Balance at Bank and Cash in Hand** ..		1,607 11 9
8,912			9,700 6 3	8,912			9,700 6 3
	Jubilee Fund:				**Jubilee Fund:**		
	Donations Received	2,202 8 0		—	Balance at Bank		2,515 6 2
	Sale of Dinner Tickets	531 12 3			**Other Funds:**		
	Transfer from International Illumination Congress Fund	116 2 0				£ s. d. Investments	Balance at Bank
		2,850 2 3			Leon Gaster Memorial ..	236 13 2	17 7 2
	Less Salaries and Incidental Expenses..	334 16 1			Trotter and Paterson Memorial Lecture	350 0 0	25 19 6
—			2,515 6 2		John S. Dow Legacy ..	2,046 5 0	310 17 6
	Other Funds: (per Receipts and Payments Accounts attached):					2,632 18 2	354 4 2
247	Leon Gaster Memorial	254 0 4			Held on behalf of National Illumination Committee	304 8 6	69 13 7
364	Trotter and Paterson Memorial Lecture	375 19 6					
2,288	John S. Dow Legacy	2,357 2 6					
514	International Illumination Congress ..	—		3,777		2,937 6 8	423 17 9 3,361 4 5
3,413		2,987 2 4					
364	Held on behalf of National Illumination Committee	374 2 1					
3,777			3,361 4 5				
£12,689			£15,576 16 10	£12,689			£15,576 16 10

A. W. GOSTT (*Hon. Treasurer*).
W. E. HARPER (*Hon. Secretary*).

Auditors' Report. We have audited the above Balance Sheet and annexed Income and Expenditure Account and have obtained all the information and explanations which we considered necessary. Proper books have been kept and the accounts, which are in agreement therewith, comply with the requirements of the Companies Act, 1948.

In our opinion the Balance Sheet and Income and Expenditure Account give respectively a true and fair view of the state of the Society's affairs at 31st December, 1958, and of the surplus for the year to that date.

Dated this 14th day of January, 1959.

3, Robert Street, Adelphi, W.C.2.

ROBERT J. WARD & Co.
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1958

1957 £		£ s. d.	£ s. d.
	Administration Expenses:		
2,725	Salaries and National Insurance	2,994 0 8	
115	Staff Superannuation Scheme	110 0 0	
504	Rent and Rates	507 1 0	
67	Lighting and Heating	75 0 1	
105	Telephone	118 3 0	
1,063	Printing and Stationery	653 12 5	
418	Postage	437 10 0	
100	Travelling Expenses	88 13 10	
132	Legal Charges	—	
343	Sundry Office Expenses	248 5 7	
5,572			5,232 6 7
389	Meetings in London		295 10 11
1,613	Expenditure of Centres and Groups		1,662 10 3
37	Audit Fee		36 15 0
7,611			7,227 2 8
1,724	Cost of Printing *Transactions*, Reprints, Technical Reports, etc.		1,988 3 4
—	Expenditure on Summer Meeting, *less* Sale of Tickets		115 9 1
58	Expenditure on Dinner, *less* Sale of Tickets		—
—	Expenditure on Industrial Lighting Conference, *less* Sale of Tickets		3 5 3
204	Expenditure on Electrical Engineers Exhibition		—
—	Transfer to Leon Gaster Memorial Fund		20 0 0
	Illuminating Engineering Publishing Co., Ltd.:		
	Cost of *Light and Lighting*	2,335 5 6	
	Less Contribution towards Administration Expenses	500 0 0	
1,445			1,835 5 6
63	Contribution to Kindred Societies		62 9 0
11,105			11,251 14 11
99	Balance, being excess of Income over Expenditure		37 16 3
£11,204			£11,289 11 2

1957 £		£ s. d.
10,066	Subscriptions and Fees	10,252 7 0
802	Sales of Publications	688 3 4
290	Interest on Investments	312 14 6
36	Interest on Bank Deposit	33 16 4
10	Premium on Redemption of Investments	—
—	Premium on Conversion of Investments	2 10 0
£11,204		£11,289 11 2

RECEIPTS AND PAYMENTS ACCOUNTS FOR THE YEAR ENDED 31st DECEMBER, 1958

Leon Gaster Memorial Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1958	246 19 4	Premiums Paid		21 0 0
War Loan Interest	8 1 0	Balance at 31st December, 1958:		
Transfer from General Fund	20 0 0	Cash at Bank	17 7 2	
		£230 3½% War Loan at cost	236 13 2	
		(*Market Value £152*)		254 0 4
	£275 0 4			£275 0 4

Trotter and Paterson Memorial Lecture Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1958	363 14 6	Balance at 31st December, 1958:		
Defence Bond Interest	12 5 0	Cash at Bank	25 19 6	
		£350 3½% Defence Bonds at cost	350 0 0	375 19 6
	£375 19 6			£375 19 6

John S. Dow Legacy Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1958	2,288 1 0	Balance at 31st December, 1958:		
Interest on Investments	69 1 6	At cost:		
		£916 11s. 1d. 3½% War Loan	876 5 0	
		£500 3% Savings Bonds 1955/65	492 10 0	
		£500 3% Savings Bonds 1960/70	477 10 0	
		(*Market Value £1,455*)	1,846 5 0	
		£200 3½% Defence Bonds	200 0 0	
		Cash at Bank	310 17 6	2,357 2 6
	£2,357 2 6			£2,357 2 6

National Illumination Committee Fund

	£ s. d.		£ s. d.	£ s. d.
Balance at 1st January, 1958	363 12 1	Balance at 31st December, 1958:		
War Loan Interest	10 10 0	Cash at Bank	69 13 7	
		£300 3½% War Loan at cost	304 8 6	
		(*Market Value £208*)		374 2 1
	£374 2 1			£374 2 1

International Illumination Congress Fund

	£ s. d.		£ s. d.
Balance at 1st January, 1958	513 10 6	Transferred to Jubilee Fund	116 2 0
Interest on Investments	7 0 0	Transferred to General Fund	404 8 6
	£520 10 6		£520 10 6

At the end of the 1957/58 session Mr. C. Dykes Brown relinquished the chair of the Education Committee after three years of most effective service and has been succeeded by Dr. C. A. Padgham. The members of the committee at the end of the year were: Dr. C. A. Padgham (Chairman), Mr. A. D. S. Atkinson, Mr. P. H. Collins, Mr. A. G. Higgins, Mr. R. R. Holmes, Mr. L. F. Needham, Mr. J. F. Stanley, Mr. D. L. Tabraham.

Centres and Groups

Two meetings of the Centres Joint Committee were held during 1958 at which most Centres were represented. These meetings are valuable not only for the business accomplished but for the greater sense of unity they engender and it is difficult to overstress the importance of this to the health of the Society. From time to time it is inevitable that sections of a nation-wide Society will pass through difficult times and it is then that the understanding and help of others belonging to the same Society are invaluable.

During the year Council was asked by the Transvaal Centre to allow its name to be changed to the "South African Centre," as it was thought that such a change would enable the scope of the Centre's work to be widened. Council agreed to the request.

The programmes arranged by Centres for the 1958/59 session are thought to be the best for many years and indicate imaginative planning. It is encouraging to see that a number of Centres are leavening the traditional formal lectures with other types of meeting including "Forums" on several subjects. It is likely that experience gained in the special meetings of the Jubilee year will result in further experiments and Council is most anxious to encourage new ventures that increase the usefulness of the Society to the members and to others interested in lighting.

Another feature of the Centre programmes worthy of note is the number of lectures not wholly concerned with lighting and which must lead to a broadening of outlook and understanding among members. A typical example was the lecture given by Sir Gordon Russell, Director of the Council of Industrial Design, to the Manchester Centre on "Lighting and Interior Decoration."

Nothing but good can come from Centres holding meetings in towns other than those where the Centre is located and Council has noted with approval, for example the visit paid by the Bath and Bristol Centre to Plymouth.

At December 31, 1958, the chairmen and honorary secretaries of the Centres and Groups of the Society were as follows:—

	Chairman	*Hon. Secretary*
Bath & Bristol	Mr. D. E. Beard	Mr. T. O. Pettit
Birmingham	Mr. L. E. Gibbs	Mr. R. C. Willdey
Cardiff	Mr. F. H. Pulvermacher	Mr. G. J. Everett
Edinburgh	Mr. G. E. L. Comrie	Mr. C. Couper
Glasgow	Mr. L. C. Rettig	Mr. A. M. Rankin
Gloucester & Cheltenham	Mr. P. R. Marshall	Mr. A. J. Lewis
Leeds	Dr. D. L. Smare	Mr. K. J. Goddard
Leicester	Mr. A. E. Bird	Mr. F. Jackson
Liverpool	Mr. T. Jones	Mr. N. Blackman
Manchester	Mr. J. D. Ducker	Mr. E. Axon
Newcastle upon Tyne	Mr. H. Ainsworth	Mr. R. P. Wingate
Nottingham	Mr. B. M. Cobbe	Mr. G. C. Small
Sheffield	Mr. K. Marshall	Mr. E. G. R. Taylor
South Africa.	Mr. M. J. Dempster	Mr. H. L. Roston
North Lancs.	Mr. J. C. Topping	Mr. H. Sutcliffe
Swansea	Mr. G. W. Timms	Mr. S. G. Gorman
Stoke-on-Trent	Mr. H. Short	Mr. J. P. Oliver
Tees-side	Mr. D. Bradshaw	Mr. P. Rose

Council appreciates greatly the service given to the Society by the officers and committee members of all Centres and Groups.

Finance

The income of the Society for 1958 was slightly in excess of expenditure but Council would reiterate the conviction expressed in the introduction to this Report, that if services to members are to be improved in these days of rising costs and if the Society is to fulfil its responsibilities to the community, continued increase in membership is essential.

Arrangements are being made by the Honorary Treasurer for a thorough examination by experts of the Society finances, and particularly its investment policy, so that the monies at its disposal may be used most efficiently.

Council agreed during the year that the "International Illumination Congress Fund" should be amalgamated with the general reserves of the Society and this has been done in the accompanying statement of accounts.

Conclusion

This Report of Council cannot be concluded without expressing the warmest thanks to Mr. Cole and his staff without whose constant devotion and ungrudging service the accomplishments it records would have been impossible. Especially has this been so in the year under review when they have had to sustain the additional strain imposed by the intricate preparations for the Jubilee. Not Council only, but all members are heavily in debt to them.

C. C. SMITH, *President.*

W. E. HARPER, *Hon. Secretary.*

Appendix 1

I.E.S. Representatives on Outside Committees

NATIONAL ILLUMINATION COMMITTEE	G. F. Cole, J. G. Holmes, L. H. McDermott, C. C. Smith, J. M. Waldram
COUNCIL FOR CODES OF PRACTICE	W. Robinson
Codes of Practice Committee for Buildings	J. G. Holmes
Codes of Practice Committee for Electrical Engineering	W. R. Stevens
PARLIAMENTARY AND SCIENTIFIC COMMITTEE	W. E. Harper
CITY AND GUILDS OF LONDON INSTITUTE ADVISORY COMMITTEE ON ILLUMINATING ENGINEERING	W. R. Stevens
COMMITTEES OF THE BRITISH STANDARDS INSTITUTION:	
Aircraft Lamps and Lampholders	A. G. Penny
British National Committee of the I.E.C.	J. N. Aldington
Cinematograph Industry Standards Committee	H. C. Weston
Cinematograph Electrical Equipment	S. S. Beggs
Cinema Studio Lighting, Lamps and Fittings	S. S. Beggs
Cinematograph Carbon-Arc Equipment	F. S. Hawkins
Auditorium and Safety Lighting for Cinemas and Theatres	S. S. Beggs
Safety Signs for Cinemas and Theatres	S. S. Beggs
Stage Electrical Accessories	E. E. Faraday
Code of Practice Committee on Street Lighting	E. Stroud, J. M. Waldram
Low Pressure Gas Mantles	F. C. Smith
Metal Windows	G. F. Cole
Illumination Industry Standards Committee	J. M. Waldram, J. G. Holmes, L. H. McDermott, G. F. Cole, C. C. Smith
Nomenclature for Illumination	W. Robinson, G. F. Cole
Lighting Fittings	W. T. F. Souter, A. W. Jervis
Diffusing Materials	J. W. T. Walsh
Fittings for Double-capped Tubular Lamps	V. F. Beuttell
Watertight Electric Light Fittings	G. W. S. Levey
Electric Lamps	W. T. F. Souter
Electric Lamps for Navigation Purposes	A. G. Penny
Tungsten Filament Lamps	A. G. Penny
Discharge Lamps	A. G. Penny
Electric Signs	E. F. Martin
Ultra-Violet Light	A. G. Penny
Co-ordination of Colours for Signal Purposes	J. G. Holmes
Colour Terminology	G. T. Winch
Photographic Electronic Flash Equipment	H. W. Cumming
Construction of Road Traffic Signs	F. C. Smith
Photographic Industry Standards Committee	A. W. Gostt
Protection Against Injurious Radiation	H. C. Weston
Tail Lights and Reflex Reflectors for Vehicles	H. F. Stephenson

Appendix 2

Sustaining Members

A.E.I. LAMP & LIGHTING CO. LTD.
Head Office, Melton Road, Leicester.

ALADDIN LIGHTING LTD.
P.O. Box 3491, Johannesburg, South Africa.

ALLOM BROTHERS LTD.
Lombard Road, Merton, London, S.W.19.

ARROW PLASTICS LTD.
Arrow Works, Portsmouth Road, Thames Ditton, Surrey.

ATLAS LIGHTING LTD.
233, Shaftesbury Avenue, London, W.C.2.

AURORA LAMPS LTD.
Old Kilpatrick, Glasgow.

BARLOW & YOUNG LTD.
55, Catherine Place, London, S.W.1.

BEADLE, T., & CO. LTD.
3-5, Castle Street, Hull, Yorks.

BEADLE EXPORT CO. LTD., T.
8, Castle Street, Hull, Yorks.
BENJAMIN ELECTRIC LTD.
Brantwood Works, Tariff Road, Tottenham, N.17.
BIRMINGHAM, CITY OF, EDUCATION DEPT.
Council House, Margaret Street, Birmingham.
BOLTON CORPORATION LIGHTING DEPT.
Marsden Road, Bolton, Lancs.
BRITISH ELECTRICAL DEVELOPMENT ASSOCIATION, THE
2, Savoy Hill, Strand, London, W.C.2.
BRITISH GENERAL ELECTRIC CO. (PTY.) LTD., THE
Magnet House, Corner Loveday and Anderson Street, Johannesburg, South Africa.
BRITISH LUMA CO-OPERATIVE ELECTRIC LAMP SOCIETY LTD.
Hardgate Road, Glasgow, S.W.1.
BRITISH OPTICAL ASSOCIATION
65, Brook Street, London, W.1.
BRITISH THOMSON-HOUSTON CO. (S.A.) (PTY.) LTD.
P.O. Box 7755, Johannesburg, South Africa.
CARTWRIGHT, J. T., & SONS LTD.
195, St. Vincent Street, Glasgow, C.2.
CHANCE BROS. & CO. LTD.
Glass Works, Smethwick, Birmingham.
CINEMATOGRAPH EXHIBITORS' ASSOCIATION OF GREAT BRITAIN AND IRELAND, THE
164, Shaftesbury Avenue, London, W.C.2.
CLAUDE NEON LIGHTS OF NEW ZEALAND LTD.
91, Hobson Street, Auckland, C.1, New Zealand.
CLEGG, E., & SON LTD.
Shore Mills, Littleborough, Lancs.
COURTNEY, POPE (ELECTRICAL) LTD.
Amhurst Park Works, Tottenham, N.15.
CROMPTON PARKINSON LTD.
Crompton House, Aldwych, London, W.C.2.
CROSSLAND, R. & A. G., LTD.
Cartbridge Lane, Walsall, Staffs.
CRYSELCO LTD.
Kempston Works, Bedford.
DAVIDSON & CO. LTD., GEORGE
Teams Glass Works, Gateshead-on-Tyne, 8.
DAVIES & CO. LTD., HUBERT
P.O. Box 1386, Johannesburg, South Africa.
DERNIER & HAMLYN LTD.
23, Newman Street, London, W.1.
DOCKER BROS.
Rotton Park Street, Ladywood, Birmingham, 16.
DOMINEC (PTY.) LTD.
P.O. Box 3269, Johannesburg, South Africa.
DORMAN & SMITH LTD.
Atherton Works, Blackpool Road, Preston, Lancs.
DOWNES & DAVIES LTD.
1-9, Stanley Street, Liverpool, 1.
EASTERN ELECTRICITY BOARD
Whersted, Ipswich, Suffolk.
EASTERN GAS BOARD
Abbey Gardens, Westminster, London, S.W.1.
EAST MIDLANDS ELECTRICITY BOARD
Mapperley Hall, Nottingham.
EDINBURGH, CORPORATION OF THE CITY AND ROYAL BURGH OF
City Chambers, Edinburgh, 1.
E.G.S. CO. LTD.
10-12 Trafalgar Street, Newcastle-on-Tyne, 1.
EKCO-ENSIGN ELECTRIC LTD.
Preston House, 45, Essex Street, Strand, W.C.2.
ELECTRICAL COMPONENTS LTD.
Components House, Ludgate Hill and Lionel Street, Birmingham, 3.
ELECTRICITY COUNCIL, THE
Trafalgar Buildings, 1, Charing Cross, London, S.W.1.
ELECTRIC LAMP INDUSTRY COUNCIL
25, Bedford Square, London, W.C.1.
ELECTRIC STREET LIGHTING APPARATUS CO. LTD.
The Foundry, Canterbury, Kent.
ELLISON LTD., GEORGE
Wellhead Lane Works, Perry Barr, Birmingham, 22b.
ENGINEERING & LIGHTING EQUIPMENT CO. LTD.
Sphere Works, St. Albans, Herts.
ENGINEERING SERVICE INSTALLATIONS LTD.
258, Gray's Inn Road, London, W.C.1
ERINOID LTD.
96, Piccadilly, London, W.1.
EVANS ELECTROSELENIUM LTD.
Potter Street, Harlow, Essex.
EVER READY CO. (GREAT BRITAIN) LTD.
Hercules Place, London, N.7.
FALKS ELECTRICAL SUPPLIES (S.A.) (PTY.) LTD.
17, Heidelburg Road, Village Main, P.O. Box 3068, Johannesburg, South Africa.
FALK STADELMANN & CO. LTD.
91, Farringdon Road, London, E.C.1.
FIELD & SON LTD., H. W.
Cable Works, Station Road, Harold Wood, Essex.
FOSTER ELECTRICAL SUPPLIES LTD.
Morden Road, S. Wimbledon, London, S.W.19.
FRENCH LTD., B.
Mill Lane, Kidderminster, Worcs.
FULFORD BROWN BROS. (1929) LTD.
Crystex Works, Regent Parade, Birmingham, 1.
G.P.O. (ENG. DEPT.)
2-12, Gresham Street, London, E.C.2.
GAS COUNCIL
Gas Industry House, 1, Grosvenor Place, London, S.W.1.
GENERAL ELECTRIC CO. LTD.
Magnet House, Kingsway, London, W.C.2.
GIRDLESTONE & CO. LTD.
23, Davies Street, London, W.1.
GRANT & SONS LTD., DONALD
St. James's Place, Edinburgh, 1.
HAILWOOD & ACKROYD LTD.
Beacon Works, Morley, Nr. Leeds.
HARRIS & SHELDON (ELECTRICAL) LTD.
Ryder Street, Birmingham, 4.
HEYWOOD & CO. LTD., S. H.
2, North Parade, Parsonage, Manchester, 3.
HEYES & CO. LTD.
Water Heyes Electrical Works, Wigan, Lancs.
HIRST IBBETSEN & TAYLOR LTD.
47-53, Chapel Street, Salford, 3.
HIVAC LTD.
Stonefield Way, Victoria Road, South Ruislip, Middx.
HOLLAND HOUSE ELECTRICAL CO. LTD.
221, St. Vincent Street, Glasgow, C.2.
HOLOPHANE LTD.
Elverton Street, Vincent Square, London, S.W.1
HUME ATKINS & CO. LTD.
New Icknield Way, Letchworth, Herts.
IMPERIAL CHEMICAL INDUSTRIES LTD. (Alkali Division)
Winnington, Northwich, Cheshire.
IMPERIAL CHEMICAL INDUSTRIES LTD. (Metals Division)
Kynoch Works, Witton, Birmingham, 6.
IMPERIAL CHEMICAL INDUSTRIES LTD. (Paints Division)
Wexham Road, Slough, Bucks.
IMPERIAL CHEMICAL INDUSTRIES LTD. (Plastics Division)
Black Fan Road, We wyn Garden City, Herts.

INDUCTIVE APPLIANCES LTD.
St. Nicholas Street, Newcastle upon Tyne, 1.

JOBLING & CO. LTD., J. A.
Wear Glass Works, Sunderland.
JORGENSEN (1956) (PTY.) LTD., A. G.
1, Long Street, Booysens, Johannesburg, South Africa.

KILPATRICK & SON LTD., JAMES
Kelvin House, River Cart Walk, Paisley.
KNIGHTSHADES LTD.
Silverhill Works, Theaklen Drive, St. Leonard's-on-Sea.

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LTD.
B.E.P. Works, Rugeley, Staffs.
LEEDS EDUCATION COMMITTEE
Education Offices, Calverley Street, Leeds, 1.
LINOLITE LTD.
Mill Works, Malmesbury, Wilts.
LITTLEWOODS POOLS LTD.
Central Maintenance Dept., Cases Street, Liverpool, 1.
LIVERPOOL, CORPORATION OF
Town Clerk's Office, Municipal Buildings, Liverpool, 2.
LONDON ELECTRICITY BOARD
46-7, New Broad Street, London, E.C.2.
LONDON TYPOGRAPHICAL DESIGNERS LTD.
90, Ebury Street, London, S.W.1.
LUCAS LTD., JOSEPH
Great King Street, Birmingham.
LUMENATED CEILINGS LTD.
Alliance House, Caxton Street, London, S.W.1.
LUXRAM ELECTRIC LTD.
72, Great Eastern Street, London, E.C.2.

MARRYAT & PLACE LTD.
40, Hatton Garden, London, E.C.1.
MERCHANT ADVENTURERS LTD.
43, Portland Road, London, W.11.
MERSEYSIDE & N. WALES ELECTRICITY BOARD
Electricity House, Love Lane, Pall Mall, Liverpool.
METALLIC SEAMLESS TUBE CO. LTD.
Ludgate Hill, Birmingham, 3.
METROPOLITAN-VICKERS SOUTH AFRICA (PTY.) LTD.
Maritime House, Loveday Street, P.O. Box 3633, Johannesburg, South Africa.
MIDLAND ELECTRIC INSTALLATION CO.
Cyprus Works, Upper Villiers Street, Wolverhampton.
MIDLANDS ELECTRICITY BOARD
Headquarters, Mucklow Hill, Halesowen, Worcs.
MORGAN CRUCIBLE CO. LTD.
Battersea Church Road, S.W.11.
MORTIMER, GALL & CO. LTD.
115-117, Cannon Street, London, E.C.4.

NEON FLUORESCENT (S.A.) (PTY.) LTD.
P.O. Box 9101, Johannesburg, South Africa.
NETTLE ACCESSORIES LTD.
Harper Road, Wythenshawe, Manchester, 22.
NEW ERA LIGHTING INDUSTRIES (PTY.) LTD.
P.O. Box 7125, Johannesburg, South Africa.
NEWEY & EYRE LTD.
102, Hagley Road, Edgbaston, Birmingham, 16.
NORTH EASTERN ELECTRICITY BOARD
Carliol House, Newcastle upon Tyne, 1.
NORTH WESTERN ELECTRICITY BOARD
Cheetwood Road, Manchester.
NORTH WESTERN GAS BOARD (Liverpool Group)
Radiant House, Bold Street, Liverpool, 1.

OLDHAM CORPORATION SURVEYORS & BUILDINGS COMMITTEE
Lighting Dept., Gas Street, Oldham, Lancs.
OLDHAM & SON LTD.
Denton, Manchester.

PHILIPS (PTY.) LTD. S.A.
Upper Railway Road, Cor. Herb Street, New Doornfontein, P.O. Box 7703, South Africa.
PHILIPS ELECTRICAL LTD.
Century House, Shaftesbury Avenue, London, W.C.2.
PRIDE LTD., F. H.
Clapham High Street, London, S.W.4.
PRUDENTIAL ASSURANCE CO. LTD.
142, Holborn Bars, London, E.C.1.

REED & CO. LTD., ALBERT E.
105, Piccadilly, London, W.1.
REVO ELECTRIC LTD.
Britannia Works, Tividale, Tipton, Staffs.
REYNOLDS (ELEC. FACTORS) LTD., FRED.
230, Wellington Street, Leeds, 1.
RILEY & SON (ELECTRICAL) LTD., JOHN
281-283, Attercliffe Common, Sheffield, 9.
RIVLIN LTD., J.
16-17, Brunswick Street, Leeds.
ROBINSON, KING & BRITISH CHALLENGE GLAZING CO. LTD.
Marshgate Lane, London, E.15.
ROGERS (PTY.) LTD., G. S.
P.O. Box 3667, Johannesburg, South Africa.
ROWLANDS ELECTRICAL ACCESSORIES LTD.
157, Hockley Hill, Birmingham, 18.

SATCHWELL & GITTINGS LTD.
Tantarra Electrical Works, Walsall, Staffs.
SCOTT & CO. LTD., JAMES
175, St. Vincent Street, Glasgow, C.2.
SIEMENS EDISON SWAN LTD.
38-39, Upper Thames Street, London, E.C.4.
SIEMENS EDISON SWAN (PTY.) LTD.
20, Simmonds Street South, P.O. Box 7404, Johannesburg, South Africa.
SIGN COMPONENTS LTD.
121-3, Camden High Street, London, N.W.1.
SIMPLEX ELECTRIC CO. LTD.
Broadwell, Oldbury, Birmingham.
S.L.R. ELECTRIC LTD.
Welbeck Works, Welbeck Road, South Harrow, Middx.
SMITH & CO. LTD., WM. ALLAN
East Silvermills, Edinburgh, 3.
SMITH & CO. (ELECTRICAL ENGINEERS) LTD., W. H.
12, York Street, Manchester, 2.
HERMAN SMITH SMITHLITE LTD.
Empire Works, Dudley, Worcs.
SNEATH LTD., J. G.
Wallwood Street, London, E.14.
SOUTH EASTERN ELECTRICITY BOARD
10, Queen's Gardens, Hove, 3, Sussex.
SOUTH OF SCOTLAND ELECTRICITY BOARD
P.O. Box 173, 351, Sauchiehall Street, Glasgow, C.2.
SOUTH WALES ELECTRICITY BOARD
St. Mellons, Cardiff.
SOUTH WESTERN ELECTRICITY BOARD
Electricity House, Colston Avenue, Bristol.
SOUTHERN ELECTRICITY BOARD
Southern Electricity House, Littlewood Green, Maidenhead.
STELLA LAMP CO. LTD.
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UDC 535.215

Measurement of Low Light Levels by the Photon Counting Method

By B. M. YOUNG, B.Sc. and L. P. COOPER, B.Sc.

Summary

Experiments are described using electron counting techniques for measuring low light levels with photomultipliers. An accuracy of 1 per cent has been achieved in measuring cathode currents of the order of 10^{-15} amp. or less with the photomultiplier cooled to −183°C. The luminous flux falling on the cathode of area 2.4 sq. in. was c.10^{-11} lumen. At higher levels, the limitations in resolution of the counting equipment available caused 20 per cent loss in counts at cathode currents of 10^{-13} to 10^{-14} amp.

The limitations of the technique for photometric applications are discussed, together with the statistical considerations governing the resolution times necessary for the amplifier and counting circuits in order to increase the range over which the counts are proportional to the luminous flux incident on the cathode.

For the past 25 years, precision photoelectric photometry has been carried out using specially constructed vacuum emission photocells of high stability and linearity of output current with incident light. Where the light levels have been low, these cells have usually been used in conjunction with electrometer triode valves and high value grid leaks up to 10^{12} ohms in D.C. amplifiers. The limiting signal detectable under these conditions with a grid leak of 10^{12} ohms is of the order of 10^{-10} lumen, but routine measurements at this low level are not practicable, since the time constant of the circuit is rather long.

In recent years photomultipliers have been widely used to obtain greater sensitivities, and experiments have been described by Winch(1) where photomultipliers have been used with a miniature electrometer triode valve in a D.C. valve bridge circuit using grid leaks up to 10^{9} ohms. The minimum detectable signal obtained was about 10^{-11} lumen.

Reference was also made by Winch(1) and has been made by Engstron(2), Yates(3) and others(4) to the possibility of measuring low light levels of this order with photomultipliers by electron counting methods. This technique has, in part, been inspired by the wide use of photomultipliers in scintillation counting for the measurement of nuclear radiation.

The present paper describes extended investigations into the accuracy and practical limitations of the electron counting technique in photometric applications.

Principle of Method

The output of a photomultiplier if observed on a cathode ray oscilloscope consists of a series of short pulses occurring at random rates and varying in amplitude. These are the bursts of electrons produced at the anode by the release of electrons from the photocathode when photons are incident upon it. The time taken for an electron released from the cathode to produce a burst of electrons at the collector through the multiplying stages is less than 10^{-9} secs.(4). The resulting voltage pulse at the collector is of magnitude $\frac{Mne}{C}$ where M=amplification factor for the multiplier, n=number of electrons each having charge e released simultaneously at the cathode and C=output capacitance of multiplier and input capacitance of succeeding pulse amplifier. The amplitude of this pulse is, of course, subject to the statistical variations in the multiplying processes in the tube and will vary within limits.

This pulse can then be amplified and counted by a suitable electronic counter. Theoretically, therefore, if the rate of release of the electrons from the cathode is less than 10^{9} per second, the resolving time of the multiplier being $<10^{-9}$ secs., then each pulse at the anode will originate from one electron released at the cathode. If the resolving time of the succeeding amplifier and counting circuits is of this order, then it should be possible to count the number of individual photoelectrons released in a given time and thereby have a sensitive and convenient method of measuring very small currents from 10^{-10} amp. down to threshold (10^{-19} amp.≡1 electron per sec.). The number of photoelectrons will be proportional to the photons incident on the cathode if the photomultiplier has a linear relationship between current and incident luminous flux.

The above argument presupposes that the electrons are released at a uniform rate but this,

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of course, does not occur in practice. They are randomly distributed with respect to time and from statistical considerations it is estimated that if the average rate of release of the electrons $=\mu$ and a is the mean time interval between the electrons (i.e. $a=1/\mu$) then the chance that the time between any two successive electrons will be less than a is given by :—

$$\int_0^{t_1/a} e^{(-t/a)}\, dt$$

where t=any time interval less than a. By application of this formula it can be shown that the maximum cathode current which can be counted in this way to an accuracy better than 1 per cent if the resolving time of the multiplier is taken to be 10^{-9} secs., will be 10^{-12} amp., i.e. an average rate of release of electrons of 10^7 per second.

The minimum limit of photocurrent which can be detected is determined by the well known dark current or noise associated with photoelectric cells. This dark current is largely caused by the release of electrons from the cathode and from the dynodes by thermionic emission and varies with temperature. It has been shown that this can be reduced in several ways, including reduction of potential to each dynode[4], application of a suitable shield potential to a layer on the outer surface of the envelope of the multiplier[5] and by cooling the multiplier[6].

Since most of these dark current electrons, like the photoelectrons, also originate from the cathode, the voltage pulses at the anode will be generally of the same amplitude as those originating from single photoelectrons. They will, however, show a larger spread in amplitude since some of the pulses will originate from the dynodes and thus will not undergo the same degree of amplification as the cathode electrons. Some reduction of dark current can therefore be obtained by using a voltage discriminator for the amplified output pulses and accepting only those above a predetermined level.

This method of reduction of dark current is not so rewarding in this application, however, as it is in scintillation counting. In the latter, the voltage pulses produced at the anode originate from bursts of electrons at the cathode and thus may be much greater in amplitude than the dark current pulses. In scintillation counting it is the amplitude of the pulse which is important since this will be proportional to the energy of the nuclear particles producing the scintillation in suitable crystals. The count due to the dark current can thus be greatly reduced by setting the acceptance level of the discriminator to cut out most of the dark current pulses and yet permit all the photoelectron pulses to be counted.

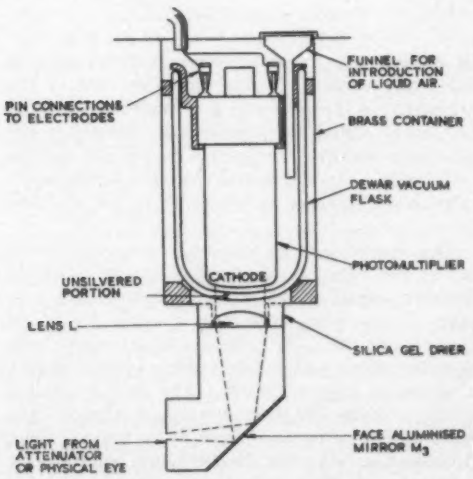

Fig. 1. Cooling unit for photomultiplier.

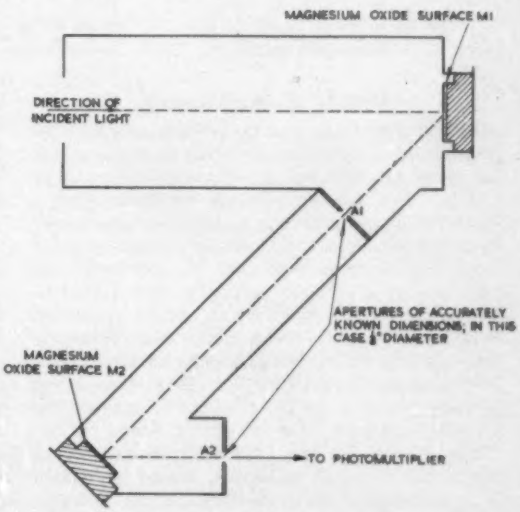

Fig. 2. Neutral light attenuator (density 8 approx.).

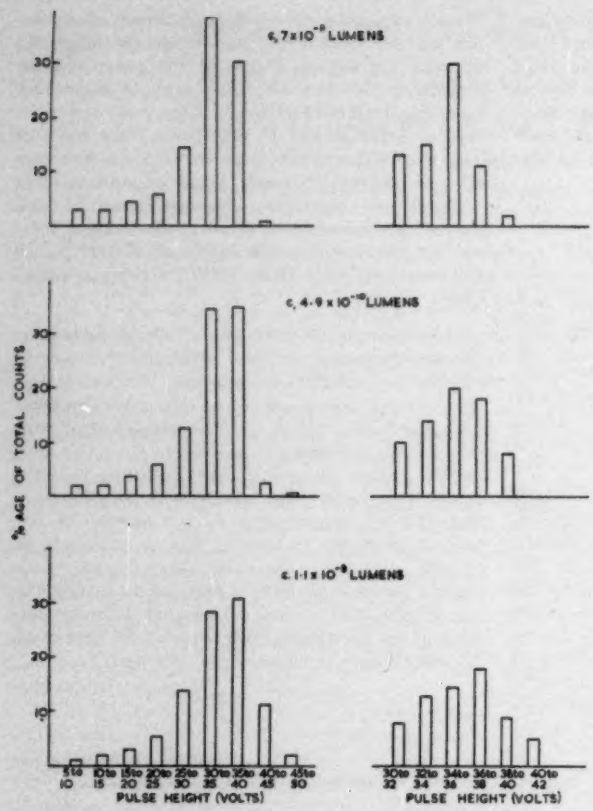

Fig. 3. Pulse height distribution curves for varying illumination levels. (Multiplier cooled to -183°C).

Details of Experiments

Experiments have been carried out to explore the possibilities of the photon counting technique, using an experimental R.C.A. photomultiplier type C7138. This was an 11-stage multiplier with a caesiumbismuth cathode. The recommended dynode potential was 90 volts per stage and the total amplification factor at this potential was c.5×10^5. The cathode sensitivity was c.30μa/L. Measurements of linearity by the additivity method using the D.C. valve bridge circuit had previously been made, from which it had been established that, over a range of about 10^{-7} to 10^{-9} lumens, i.e. cathode currents of 10^{-13} to 10^{-14} amps., the response was linear.

The housing for the photomultiplier shown in Fig. 1 was designed so that it would ultimately fit on to the exit tube of the Physical Eye Spectrophotometer and Colorimeter and also could be used in conjunction with a neutral light attenuator of special form(1) constructed for the purpose of the experiments. A cross sectional view of the attenuator is shown in Fig. 2. Liquid air could be introduced into the vacuum flask in which the photomultiplier was suspended, to cool the cathode to −183°C. It was found that the temperature could be maintained at this value for two to three hours.

The amplifying and counting circuits consisted of a two-stage head amplifier with cathode follower output, which was mounted on the cover plate of the photomultiplier housing giving an overall gain of c.18. The negative pulses were then fed into a three-stage pulse amplifier having a maximum gain of 20,000. The output was fed into a voltage discriminator which enabled the pulse height acceptance level to be varied. The output pulse from the discriminator section then operated a 1 Mc/s electronic counter.

Pulse height analyses were made with this

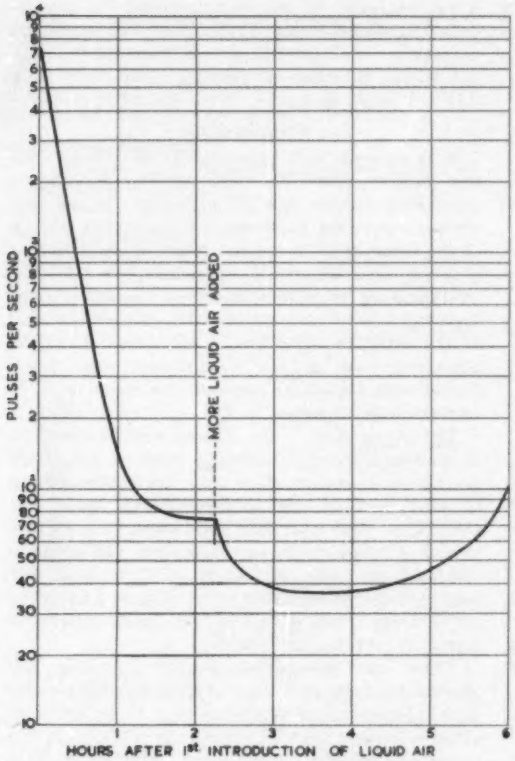

Fig. 4. Typical cooling curve after the introduction of liquid air into photomultiplier housing. Noise counts at E.H.T. 800 volts.

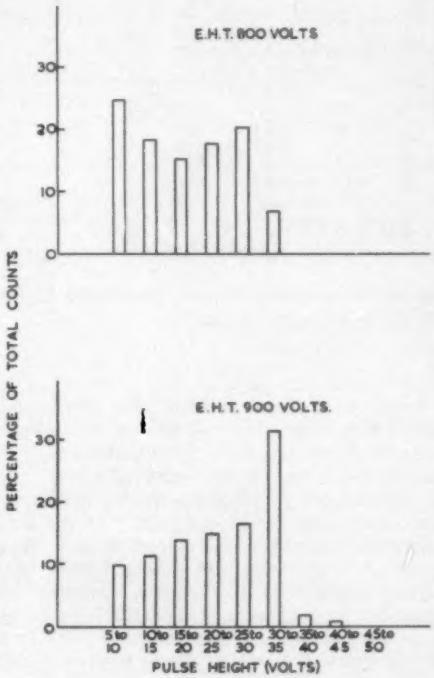

Fig. 5. Pulse height distribution curves for noise at 250°C.

equipment for three different light levels with the photomultiplier operating at 900 V. e.h.t. supplied from a highly stabilised power unit. The light source used during the experiments was a 100-volt 100-watt projector lamp operating at a colour temperature of 2,800°K. The measurements were taken with the photomultiplier cooled by the introduction of liquid air in order to reduce the dark current to negligible proportions. These results are shown plotted in Fig. 3.

Fig. 4 shows the effect of cooling on the number of dark current pulses, and it will be seen that when the photomultiplier is cooled to −183°C, these are reduced to less than 1 per cent of the number occurring at room temperature. A distribution of the dark current pulses at room temperature but with the same pulse amplification and e.h.t. voltage as before, was also obtained and is given in Fig. 5.

The relation between the total number of pulses counted and the light level is given in Fig. 6.

Discussion

From Fig. 6, it will be seen that the number of pulses counted was proportional to the incident luminous flux up to a counting rate of about 10^4/sec., i.e. 10^{-15} amp. At an average counting rate of about 10^5 pulses per second the loss in counts was about 20 per cent. This is consistent with the known resolving time of the pulse amplifier which was of the order of 3μs.

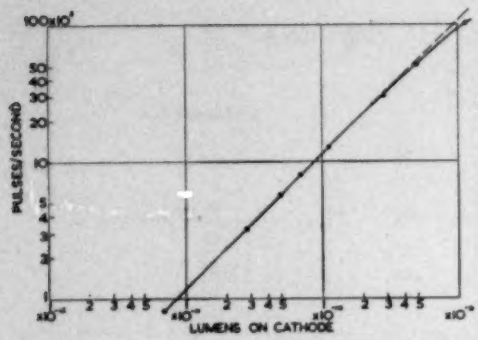

Fig. 6. Relationship between illuminaton level and number of pulses per second.

From an examination of the pulse height distribution diagrams it will be seen that the peak pulse height for the dark current counts coincides roughly with that for the lowest light level. This fact would tend to confirm that individual electrons were being resolved at this level. At the higher light levels, however, the spread in pulse height is rather larger and the average pulse height slightly higher. It is probable, therefore, that some of the higher pulses originate from more than one cathode electron, which results in the 20 per cent loss in counts at this level.

In using this technique for photometric purposes, consideration must also be given to the repetition accuracy which can be achieved when counting random pulses and the minimum time over which a count must be made. To obtain a repetition accuracy of 1 per cent, whatever the rate of counting, the minimum time over which the count is made will obviously vary. If counts* are made in each a number of equal time intervals, these counts would be expected to vary from the average count, n, in a random manner. This variation can be measured by the standard deviation which, for this kind of phenomenon, is approximately $*\sqrt{n}$ or $1/\sqrt{n}$ of the total count.

If repetition accuracy is to be within 1 per cent, whatever the counting rate, then $1/\sqrt{n}$ must be <0.5 per cent of the total number of counts, i.e. a minimum total count of 40,000 would be necessary. At currents of 10^{-12} to 10^{-15} amp. this means the time of counting would vary from 0.04 sec. to 40 secs.

Conclusions

It is evident from these results that even with the limited resolving time of the equipment available, namely 3μs, it is possible to use the electron counting technique for measuring signals of the order of 10^{-11} lumen or less to an accuracy of 1 per cent when the photomultiplier is cooled by liquid air to reduce the dark current counts. This light level corresponds to a cathode current of the order of 10^{-15} amp. The limiting signal detectable with the R.C.A. multiplier used, when cooled with liquid air, was of the order of 10^{-14} lumen, i.e. 10^{-18} amp.

The upper limit to the accuracy of this method is governed by the resolving time of amplifiers and counters and ultimately by the resolving time of 10^{-9} secs. of the photomultiplier itself. If this latter were the only limitation, then for the counting losses to be <1 per cent, the average counting rate possible would be 10^{7} pulses per second, i.e. corresponding to a cathode current of 10^{-13} amps., which would be produced by a signal of 10^{-7} to 10^{-8} lumens.

There are several advantages in using the photon counting technique at these low light levels if the difficulties of resolving time could be overcome to extend the range over which the counting losses are less than 1 per cent. The accuracy is much less dependent on dynode potential than the D.C. method, the stability requirements for the e.h.t. supply are therefore less critical. The technique is much quicker and easier than the balancing which has to be performed by the operator in the D.C. bridge amplifier technique, and since the result is presented in numbers on an electronic counter, this lends itself more readily to automatic printing of results and subsequent computation.

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* Poisson's formula, which relates to the counting of random events, implies that if the mean count over a large number of equal time intervals is n, then the probability that r counts will occur in any given interval is $n^r e^{-n}/r!$. For small values of n, the distribution of r is very skew. For large values of n, the curve approximates to a Gaussian curve with S.D. $= \sqrt{n}$

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Session 1959-1960

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* Filling casual vacancy for one year; eligible for re-election.

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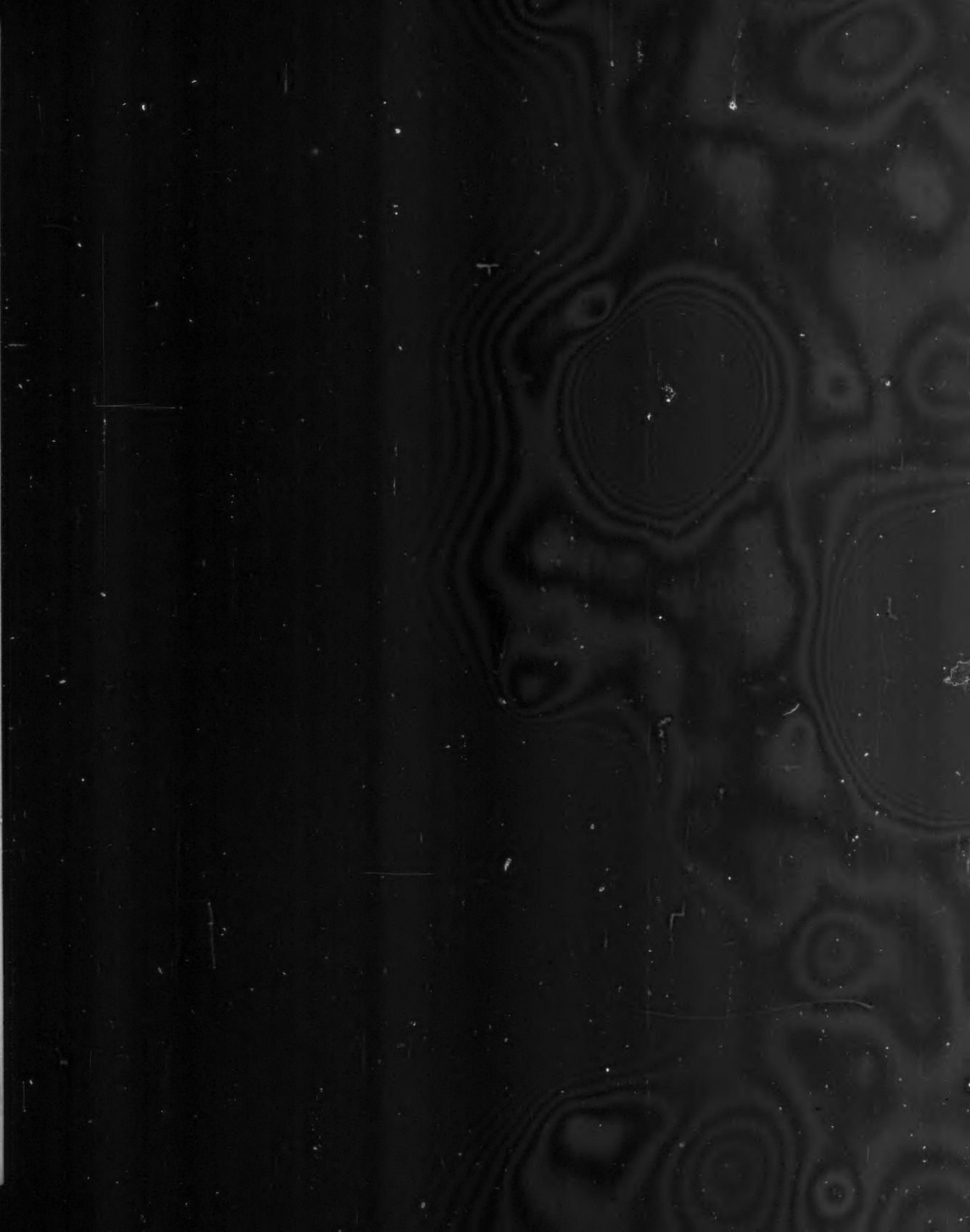
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